

Report of the

**SUBREGIONAL WORKSHOP TO PROMOTE SUSTAINABLE
AQUACULTURE DEVELOPMENT IN THE SMALL ISLAND
DEVELOPING STATES OF THE LESSER ANTILLES**

Vieux Fort, Saint Lucia, 4-7 November 2002



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ISBN 92-5-104993-9

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PREPARATION OF THIS DOCUMENT

The FAO Fisheries Department has embarked on a programme of promoting sustainable increases in the production of food fish from aquaculture activities in developing countries, including Small Island Developing States (SIDS). Mindful of the status of the world's marine capture-fisheries the goal of the department has been to assist SIDS to position themselves to mitigate food insecurity, while at the same time ensuring that their aquaculture practices are compatible with their ecosystems. In the case of the SIDS of the Lesser Antilles the assistance took the form of a workshop to examine the past and ongoing aquaculture experiences and to elaborate the institutional and policy constraints and opportunities for sustainable aquaculture development, in the future.

This report is the record of the proceedings of that workshop. It also includes the national aquaculture-status reports of the countries that were represented and the papers presented by resource persons.

The report was prepared by the FAO Subregional Office, in close collaboration with the Development Planning and the Inland Water Resources and Aquaculture Services of FAO, Rome.

Distribution:

All FAO Members and Associate Members
Participants at the Session
FAO Fisheries Department
Fishery Officer in FAO Regional Offices

Lovatelli, A.; Walters, R.; Anrooy, R. van (eds.)

Report of the Subregional Workshop to Promote Sustainable Aquaculture Development in the Small Island Developing States of the Lesser Antilles. Vieux Fort, Saint Lucia, 4–7 November 2002.

FAO Fisheries Report. No. 704. Rome, FAO. 2003. 122p.

ABSTRACT

The workshop was organized by the FAO Subregional Office for the Caribbean in collaboration with the Development Planning and Inland Water Resources and Aquaculture Services of the FAO Fisheries Department, Rome. It was hosted by the Government of Saint Lucia, and attended by 15 participants from seven countries, four regional institutions and the FAO Fisheries Department.

The syntheses of the national experiences and status of aquaculture development in the Lesser Antilles reflected a significant level of diversity in the scale of activities among the island nations; they also revealed many similarities in the results and present status of aquaculture development in the subregion. The case studies elicited very positive comments and enquiries from the country representatives.

In the plenary deliberations, to identify the constraints to and opportunities for developing aquaculture sustainably in the subregion, participants recognized the need to rank the aquaculture development activities based on individual country-priorities and stage of development.

The workshop agreed that participants would consult with the decision-makers in their respective countries and communicate a priority-list of needs for possible technical assistance to the technical secretary of the workshop. It was also agreed that such a list would be used to identify common themes that could form the basis for a possible subregional Technical Cooperation Programme (TCP) project proposal.

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SUMMARY OF RECOMMENDATIONS AND PROPOSAL FOR FURTHER ACTION

The workshop participants noted the results of the many previous attempts to develop aquaculture in the subregion. They also identified the following steps that should be taken to facilitate the development of sustainable aquaculture in the SIDS of the Lesser Antilles:

- 1) Incorporate aquaculture into national development plans and strategies;
- 2) Formalizing an aquaculture development policy (including environment and fiscal incentives);
- 3) Legal framework development; Establish small-scale pilot projects for technology transfer and its evaluation;
- 4) Economic feasibility studies and marketing analysis for aquaculture proposals;
- 5) Allocate resources (government commitment) for aquaculture;
- 6) Strengthen aquaculture related institutions (including monitoring and regulatory systems, capacity building, research);
- 7) Appropriate technology (development & dissemination);
- 9) Identify reliable sources of inputs and create access to inputs (broodstock, feed, fingerlings, equipment);
- 10) Establishing administrative procedures for smooth Evaluation and Approval of projects;
- 11) Code(s) of Best Practice development (under private-public partnerships); and
- 12) Attract private sector involvement/investment.

The participants recommended that the steps should be prioritized taken in the order suiting the stage of development of aquaculture in a particular subregional country.

They also recommended that a concerted effort should be made to raise the awareness of the opportunities for sustainable aquaculture development among potential aquaculture stakeholders, decision-makers and natural resources managers in the Lesser Antilles.

It was suggested that an immediate follow-up activity to the workshop could take the form of a Technical Cooperation Programme (TCP) project proposal based on the common priority-needs communicated to the workshop secretariat by the countries that participated.

PART I - MEETING REPORT

BACKGROUND AND OBJECTIVES

1. At the special FAO Ministerial Conference on Agriculture in Small Island Developing States (SIDS) held in 1999, the participating countries expressed their commitment to pursue efforts to achieve food security and to implement development policies and programmes which would secure the sustainability of agriculture, forestry and fisheries sectors in SIDS. Specific to aquaculture, the Ministerial Conference recognized the need to collaborate with the international and scientific communities in both the public and private sectors to:

- Introduce or strengthen aquaculture and inland fisheries where feasible and appropriate;
- Ensure that aquaculture practices are compatible with their ecosystems; and
- Establish networks to facilitate exchanges of technical information.

2. FAO included under its current Programme of Work for the 2002-2003 biennium a sub-programme activity on aquaculture development. For the Caribbean region it is intended to promote aquaculture and inland fisheries and increase their contribution to the achievement of food security. Therefore, a number of case studies and analyses of key aspects of aquaculture and inland fishery production have been carried out. Some of the outputs of these activities, specific to the SIDS of the Lesser Antilles, include contributions towards:

- Identifying and analyzing constraints and commercial and or small-scale rural aquaculture development;
- Identifying mechanisms for promoting regional and subregional information exchange, in aquaculture development and management strategies; and
- Identifying opportunities for promoting sustainable and listing the policy and legal initiatives that governments can use to promote sustainable aquaculture development.

3. Efforts to promote aquaculture development among the SIDS of the Lesser Antilles were initiated in the early 1980s. In 1993 the Italian-funded FAO-AQUILA II project on 'Support to Regional Aquaculture Activities in Latin America and the Caribbean' (GCP/RLA/102/ITA) recognized the different potentials for developing aquaculture in the region following a review of the industry. Subsequently, in co-operation with the Caribbean Community (CARICOM) Secretariat, a project on Caribbean Aquaculture Development (CARAD), aimed at institutional strengthening and increasing co-operation among regional institutions was prepared.

4. The main objectives of the CARAD project proposal are still relevant. However, since the project did not attract the anticipated funding it was not implemented. In a real sense, therefore, the present workshop can be considered as an attempt to use the approach suggested in the original CARAD project proposal to refocus on the status of, and the elements of relevance to, aquaculture development in the SIDS of the Lesser Antilles.

5. At the Twenty-first session of the FAO *Committee on Fisheries* (COFI), held in Rome, March 1995, "some delegations underscored the potential importance that the development of aquaculture might play in future in SIDS. It was noted that aquaculture could

be vital for food and economic development, and could permit a reduction in fishing effort where this was called for". At the same Session, several delegations considered that FAO assistance to SIDS should focus on six main areas, among which was "aquaculture and inland fisheries conservation, management and development". Although the issue of aquaculture development in the SIDS was raised during various subsequent sessions it never managed to gain a priority status, which made it difficult for FAO to support aquaculture development in the SIDS through regular budget funds.

6. In view of the above, FAO organized the Workshop on the Development of Sustainable Aquaculture in the Small Island Developing States of the Lesser Antilles with the aim of assisting the participating governments in their decision making processes related to aquaculture development strategy and policy development. The proceedings and conclusions are detailed in this report.

ATTENDANCE

7. The workshop was attended by 15 participants from seven countries in the region, from four regional institutions, and from the Fisheries Department of the Food and Agriculture Organization of the United Nations (FAO) and the FAO Subregional Office for the Caribbean (FAO SLAC). The countries represented included Antigua and Barbuda, Barbados, Grenada, Saint Vincent and the Grenadines, Saint Kitts and Nevis, Saint Lucia and Trinidad and Tobago. The representatives from the Bahamas and Dominica did not attend, but submitted updated reports on the status of aquaculture in their respective countries. The list of participants is attached as Appendix B to this report.

PROCEEDINGS

Opening Ceremony

8. The workshop started with an opening ceremony in which Mr Randolph Walters, Fishery Officer in the FAO Subregional office for the Caribbean, welcomed the participants on behalf of the Director General of FAO, Dr Jacques Diouf and from the Assistant Director-General of the FAO Fisheries Department, Mr Ichiro Nomura. He proceeded to explain the purpose of the workshop and provide a historical background on FAO's past activities in support of aquaculture development in the subregion.

9. He thanked the Government of Saint Lucia for hosting the workshop and introduced its representative to deliver welcoming remarks and to officially open the workshop.

10. Following the introduction, the Chief Fisheries Officer of the Ministry of Agriculture, Forestry and Fisheries of Saint Lucia, Mr Vaughn Charles, conveyed regards from the Honourable Minister, Mr Calix George. The speaker thanked FAO for having organized the workshop in Saint Lucia and extended a warm welcome to the participants. He then took the opportunity to discuss the importance of food security and the potential contribution aquaculture can play in achieving food security in the SIDS of the Lesser Antilles. The speaker stressed the opportunities for aquaculture with regard to providing products to the tourism sector on the islands and to the Saint Lucia school-feeding programme.

11. The speaker mentioned the recent initiatives taken by the Saint Lucia Fisheries Department in producing fish feeds and support to farmers with these feeds and fingerlings. He highlighted the difficulties that aquaculture operators have experienced in sourcing affordable commercial feeds to ensure competitiveness with marine capture fisheries.

12. He also mentioned the potential for regional-level co-operation under the Caribbean Regional Fisheries Mechanism (CRFM), and the high priority given to aquaculture in the medium term plan of the CARICOM Fisheries Unit. In closing, he expressed the hope that the workshop recommendations will include ideas on how to get the costs related to running an economically viable aquaculture enterprise down and how to increase aquaculture production.

Working Session

13. Mr Walters was elected as chairperson for the workshop. The agenda was discussed and subsequently adopted. The agenda is attached as Appendix A to the present report.

Presentation of Technical Papers

14. The working session was opened with a synthesis of national experiences and status of aquaculture development in the Lesser Antilles following the same format used in the AQUILA II project in order to ensure historical comparisons (see Part II of the report). A Compendium of Fisheries Statistics (extracted from FAO Fishstat Plus) containing the aquaculture production for the Lesser Antilles SIDS and the Bahamas, was distributed as a workshop document. The participants were acknowledged for having submitted their country reports in advance, making it possible to elaborate the synthesis. While noting that national reports and the production figures in the compendium had minor differences, most participants provided some clarifications to their country's status and related personal experiences.

15. The following reports were subsequently delivered:

Marketing Opportunities for Aquaculture Products in the Lesser Antilles

16. Mr Raymon Van Anrooy, FAO Fishery Planning Officer, made a presentation focusing on the following issues:

- Trade in fishery products by SIDS of the Lesser Antilles and Bahamas;
- Markets for aquaculture products in the USA and the EU;
- Current trends in and prospects for fish consumption; and
- Issues of importance to commercially oriented aquaculturists.

17. The discussion which followed focused on fishery product quality standardization, food safety and export barriers encountered, as some of the SIDS of the Lesser Antilles are (still) not allowed to export fishery and aquaculture products to the EU. Many participants conceded that there was a local market for aquaculture products, which cannot be satisfied at present from local production. They also identified issues such as: the relative high prices of aqua-feeds, inadequate and unreliable support systems and infrastructure and access to credit as major dis-incentives to aquaculture development in the subregion.

18. The importance of the CARICOM and Organization of Eastern Caribbean States (OECS) organizations in assisting ways of improving access to the regional and international markets was recognized. The full presentation is included in Part III of the report.

Aquaculture Development of Red Drum (*Sciaenops ocellatus*) in Martinique and the French West Indies

19. Mr Jean Claude Dao of the IFREMER (French Research Institute for Exploitation of the Sea) station in Martinique presented a report on the status of mariculture development of red drum (*Sciaenops ocellatus*) in the French island. He described the techniques used in red drum culture including broodstock maintenance and spawning, larval rearing and grow-out management.

20. The presentation continued with an overview of the steps being taken to improve rearing techniques of the red drum using marine cages and the strategies adopted by IFREMER in transferring the technology to the private sector. Finally, he described some of the risks of mariculture activities and the solutions developed during the pilot phases; he also suggested some of the basic requirements and conditions that can facilitate the transfer of the red drum aquaculture technology to other Lesser Antilles islands. The presentation is included in Part III.

21. During the discussion some participants requested additional information on the extension services being supplied to farmers and the experiences with hurricane damage to the grow-out cages. Mr Dao indicated that there are eight collaborating farmers to whom IFREMER provides extension services, including juveniles for use in grow-out facilities. The speaker also reported that the cages can be submerged to minimize hurricane damage.

Tilapia Production Systems for the Lesser Antilles and other Resource-Limited Tropical Areas

22. The paper was presented by Mr James Rakocy of the University of the Virgin Islands (UVI). He started by presenting background information on the situation with respect to resources that tropical islands may lack (water supply, soil type, declining supplies from capture fisheries and topography) or have in limited amounts available to justify the establishment of tilapia production systems. He discussed three tilapia production systems: 1) cage culture in small ponds; 2) greenwater tank culture; and 3) aquaponics, a system that combines fish culture with plant culture. The speaker reviewed the techniques, materials, methods (including costs) and the results of his work (at the UVI) with floating cages in ponds to intensively produce marketable tilapia.

23. Mr Rakocy continued to describe the processes involved in the construction and operation of greenwater tank culture producing tilapia. He highlighted the processes of bio-conversion, mechanical aeration and bio-filtration, but cautioned listeners of the need for regular monitoring of this system. He also advised participants that the greenwater tank system has recently been adjusted and is now available for commercial aquaculture in small islands.

24. In describing the aquaponics system, for intensive tilapia production in combination with hydroponic vegetables and other crops such as culinary herbs and medicinal plants, the speaker indicated that the tilapia provided most of the nutrient requirements for plant growth

in the system. He described the various adjustments and changes that had to be made to the system while changing components such as tilapia stocking density and vegetable plant species.

25. The speaker detailed that the selection of the most suitable tilapia production system would depend on the local circumstances. He described that the various systems can be applied on different scales, which make them suitable to contribute to rural family diets and income as well as to large-scale commercial tilapia aquaculture. He argued that hydroponics plants extend water use and reduce discharge to the environment; hence integrated systems require less water quality monitoring than individual systems and that the cost savings can increase profit potential.

26. The speaker concluded that large-scale projects would require some preliminary experience or the availability of advance technical supervision and training, at the outset. The presentation appears in Part III of the report.

Scallop Culture in Bermuda: A Model for the Lesser Antilles?

27. Ms Samia Sarkis-Hillier of the Bermuda Biological Station for Research (BBSR) delivered this presentation. She presented the technical details of the aquaculture development process of two local scallop species (*Argopecten gibbus* and *Pecten ziczac*) in Bermuda. She also described the strategies used to carry the process to commercial production as well as to cultivate acceptance at the local markets.

28. The speaker indicated that the environmental, administrative and socio-economic conditions existing in Bermuda were suitable to facilitate the development of scallop culture, from the experimental to the commercial stages. Some of the conditions she mentioned included: good water quality, no income tax and the potential of embargo on imported similar products, and high local prices for seafood and high market demand.

29. In addressing the question of the feasibility of replicating scallop culture in the Lesser Antilles, Ms Sarkis-Hillier indicated that the turn-key technology is available, the species are tropical, and the hatchery facility costs are relatively low. She cautioned that issues such as zoning of aquaculture areas, leasing of the seabed and environmental monitoring of water quality and aesthetics would have to be considered at the outset.

30. Many participants expressed interest in having access to the scallop culture technology, particularly the participant from Antigua and Barbuda who indicated that “fisheries officials in her country were concerned about a noticeable increase in harvesting pressure on a native bivalve (*Lucine* sp.)”. She speculated that it might protect the wild bivalve stocks from over exploitation if the technology proved adaptable for culturing them. Ms Sarkis-Hillier indicated that arrangements to establish pilot projects to transfer the scallop culturing technology to the Turks and Caicos Islands and Cuba were being pursued.

Enabling Policy Frameworks for the Promotion of Sustainable Aquaculture in the Lesser Antilles

31. Mr Raymon Van Anrooy presented the paper, on this topic. It was intended that the presentation would serve as a departure point for the plenary discussions. The speaker commenced his presentation by giving some background on the macro-economic and

aquaculture sector specific policies that could facilitate sustainable aquaculture development in the Lesser Antilles. The full presentation can be found in Part III. The main issues discussed by the speaker were:

- Macro-economic and sectoral policies (e.g. COFI, CCRF, CRFM, Good governance);
- Farm level policies (e.g. related to input subsidies, grants, research and extension);
- The relevance of the Code of Conduct for Responsible Fisheries (CCRF) to aquaculture development in the SIDS of the Lesser Antilles; and
- The pre-requisites for aquaculture development in the SIDS.

32. The subsequent discussion focused on aquaculture development experiences of the SIDS of the Lesser Antilles. A country by country overview was requested by some of the resource persons. The information presented during these overviews complemented the earlier information in the 'Regional synthesis'.

33. The discussions showed that there were significant differences in the levels of aquaculture activities between countries in the region; at the same time they also revealed many similarities. For example, the sentiments expressed may be summarized as follows:

- all the countries had some level of aquaculture activities and failures in the past;
- some countries have very little ongoing aquaculture activities at present;
- generally, there is very limited land space available for inland aquaculture development, so mariculture is seen as the best option;
- acceptance of tilapia among consumers is generally low (except for red tilapia);
- some governments want to diversify their countries' agricultural sector (away from banana and sugar cane) and consider aquaculture as one of the options;
- aquaculture is barely mentioned in national fisheries laws, which are generally outdated.

34. Notwithstanding the diversity of experiences expressed, there was consensus among the participants that the aquaculture technologies described in the case studies could improve their respective aquaculture development status. Some enquired about the possibilities of setting-up pilot projects in their countries. The FAO officers responded by suggesting that one possible vehicle which can be used to facilitate the transfer of aquaculture technology among the countries was the FAO Technical Cooperation Programme (TCP). It was suggested that after participants had consulted further with their national fishery administrators formal communications could be initiated to seek to access facilities such as the FAO-TCP or other possible sources of international assistance.

PLENARY DISCUSSIONS ON POLICIES AND INSTITUTIONAL STRATEGIES FOR AQUACULTURE DEVELOPMENT IN THE LESSER ANTILLES

35. In addressing this agenda item, it was originally intended that the participants would be separated into two groups for each to focus on the following tasks:

- to identify the subregional aquaculture policy constraints and opportunities; and

- to identify the institutional constraints and opportunities in the subregional aquaculture development practices.

36. Because of the limited number of participants, it was suggested to work together instead of dividing into smaller groups as the initial agenda had detailed.

37. The plenary discussion elaborated on the critical issues and realities of aquaculture development in the SIDS of the Lesser Antilles. The participants identified the overall objectives of aquaculture as “Contributing to the achievement of food security” and “Contributing to the sustainable use of the aquatic resources of the Lesser Antilles”; they identified the direct objective as “achieving increased aquaculture production in the Lesser Antilles”.

38. The plenary acknowledged various important steps that should be taken to reach the objectives of developing the aquaculture sector. Recognizing the fact that there is hardly any aquaculture development taking place in the SIDS of the Lesser Antilles at present, the following steps were suggested:

- Incorporate aquaculture into national development plans and strategies;
- Formalizing an aquaculture development policy (including environment and fiscal incentives);
- Legal framework development;
- Establish small-scale pilot projects for technology transfer and its evaluation;
- Economic feasibility studies and marketing analysis for aquaculture proposals*;
- Allocate resources (government commitment) for aquaculture;
- Strengthen aquaculture related institutions (including monitoring and regulatory systems, capacity building, and research);
- Appropriate technology (development and dissemination*);
- Identify reliable sources of inputs and create access to inputs (broodstock, feed, fingerlings, equipment);
- Establishing administrative procedures for smooth Evaluation and Approval*;
- Code(s) of Best Practice development (under private-public partnership); and
- Attract private sector involvement/investment*.

After considerable discussion the steps marked with (*) were seen as being covered already by the other steps, and therefore could be left out.

The constraints and opportunities identified for each of the recommended steps are the following:

A. *Incorporate aquaculture into national development plans and strategies*

Constraints:

- Not enough priority is given to CCRF follow-up on aquaculture related issues
- No aquaculture strategies and plans available to incorporate into general development plans
- Aquaculture has not been considered a priority by the national governments
- Institutional capacity to develop aquaculture strategies and plans is not available

Opportunities:

- Demonstrate to Government that aquaculture can contribute to the achievement of food security, generating income and creating employment
- Emphasize that aquaculture should be part of any diversification strategy, can contribute products for the tourism sector and for export
- Develop institutional capacity to formulate aquaculture strategies and plans
- National fisheries departments should take lead in development of sectoral plans, with stakeholder consultation/involvement
- Comply with international agreements/guidelines (such as the CCRF)

B. *Formalizing an aquaculture policy development (including environment and fiscal incentives)*

Constraints:

- No clearly defined/documented policies on aquaculture (including fiscal incentives and environmental incentives)
- Limited number of aquaculture strategies available to build policies on
- Limited incentives packages to promote aquaculture development
- Limited local experiences to guide policy formulation in aquaculture
- Competition for limited resources (e.g. with tourism, agriculture and capture fisheries sectors)
- In some instances, national policy strategy is away from agriculture and similar activities
- Limited zoning is carried out (land, water, coastal)
- (Results of past projects suggest that there are limited options available)

Opportunities:

- Focus on integrated approach of development
- Draw on existing experiences within the region as well as beyond in relation to policy development at national and regional levels
- Providing incentives to small-sector as aquaculture do not have to be costly for the government
- Strengthen and promote regional cooperation in aquaculture development (including trade arrangements)
- Include aquaculture in the zoning policies & processes.

C. *Legal framework development*

Constraints:

- Existing fisheries legislation includes only limited references to aquaculture
- Limited institutional capacity to formulate proper aquaculture legislation
- Limited and outdated laws
- No enforcement of existing regulation
- Laws related to water (access) rights are not in place (yet)
- Laws are not harmonized within the region
- Limited consultation between concerned agencies and with stakeholders

Opportunities:

- Upgrade existing fisheries legislation with specific reference to aquaculture, CCRF and relevant treaties and agreements
- Establish clear regulatory and monitoring systems
- Establish clear and simple administrative procedures to facilitate implementation
- Develop mechanisms for consultation with stakeholders
- Encourage harmonization of legislation within the region through existing (sub) regional bodies such as CRFM and OECS - Environmental and Sustainable Development Unit (ESDU).

D. *Establishment of small-scale pilot projects for technology transfer and its evaluation*

Constraints:

- Negative attitudes as a result of many bad experiences in aquaculture in the past
- Limited private sector involvement in past experiences and projects
- Ineffective human resource management to make pilot projects a success
- Inadequate resources to allow government officers to implement pilot projects properly
- Lack of information and training in existing technologies
- No proper evaluation procedures/mechanisms to validate results of experiences
- No follow-up mechanism to implement successes
- Proper documentation, preservation and transfer of information has been lacking
- Cultural bias towards/against certain products/species
- Lack of proper feasibility studies, including market analysis
- Insufficient planning involved in technology transfer
- Lack of accountability
- In some instances limited participation of relevant government agencies in past experiences and projects.

Opportunities:

- Existing technologies available in the region
- Establish mechanism or networks for exchange of information (including documentation), utilizing existing agencies such as CRFM, OECS, etc.
- Develop a planned approach for technology transfer (including exchange of information, skills, personnel) taking in consideration traditions and cultural biases
- Develop monitoring and reporting systems to ensure accountability and transparency
- Promote and encourage private sector stakeholder participation in projects
- Develop and promote public education and awareness programmes
- Conduct economic feasibility studies including market, financial and business analysis at different stages of implementation

F. *Allocate resources (government commitment) for aquaculture*

Constraints:

- Lack of or inadequate resources for aquaculture development
- Competition for government resources between sectors
- In some cases lack of political will within the government to make commitments to the sector
- Lack of aquaculture advisory/stakeholders bodies to advise the government
- Insufficient data and information available to adequately inform government
- Information/data flow between departments of fisheries and Government is not functioning properly
- Inadequate project formulation/preparation/planning capacity within fisheries departments

Opportunities:

- Develop/establish aquaculture advisory committees
- Improve information and data collection and analysis systems
- Improve strategic planning and decision making processes
- Demonstrate commitment to development of aquaculture by providing and accessing available funds.
- Encourage and support regional collaboration and information exchange for greater cost effectiveness
- Encourage private sector and financial institutions to invest in aquaculture by providing specific incentives

G. *Strengthen aquaculture related institutions (including monitoring and regulatory systems, capacity building, and research)*

Constraints:

- Poor strategic and human resources planning in fisheries departments
- In some cases only a limited number of aquaculture staff available
- Lack of collaboration between fisheries departments and other departments (e.g. environmental) and research and training institutions
- Limited transfer of knowledge at national level after regional initiatives resulting in lack of continuity
- Inadequate support systems and infrastructure for aquaculture development
- Inadequate funding for institutional development

Opportunities:

- Facilitate strategic and human resource planning processes within fisheries departments
- Further improvement of regional collaboration between fisheries departments in the area of aquaculture
- Strengthen and/or create regional centres of excellence in aquaculture research and training
- On-going opportunities for capacity building of fisheries/aquaculture staff
- Encourage governments to appoint national focal points for aquaculture development to promote networking and ensure continuity and information exchange

- Identify possible sources of funding (public and private, NGOs, donors) for institutional strengthening

I. *Identify reliable sources of inputs and create access to inputs (broodstock, feed, fingerlings and equipment)*

Constraints:

- Lack of high quality broodstock, appropriate feed, fingerlings and equipment in sufficient quantities at national level
- High relative costs of inputs related to (the production and transport of) small quantities required
- Inadequate planning of production processes and related to ordering of necessary inputs
- Lack of participation/consultation with and among stakeholders in the planning process

Opportunities:

- Ensure that support systems are in place through proper planning
- Centralize purchasing wherever possible
- Identify aquaculture enterprises at national and regional level which can assist in sourcing and accessing inputs
- Establish vertical chain cooperation (e.g. between feed industry, aquaculturists, processors) in the aquaculture products chain

K. *Code(s) of Best Practice development (under private-public partnership)*

Constraints:

- Lack of knowledge of CCRF and specifically the articles on aquaculture development
- Lack of knowledge on standards for food safety and health issues (HACCP, ISO, CODEX, etc.)
- Lack of understanding of implications of not adhering to codes of best practice
- Lack of organization among aquaculturists (private sector)
- Weak linkages between public and private sector aquaculture stakeholders

Opportunities:

- Improve the image of the sector and its products among consumers
- Raise awareness on CCRF and related aspects among stakeholders
- Fisheries Departments need to provide training regarding CCRF issues and standards
- Promote good management practices in the whole industry
- Encourage the formation of private sector organizations/associations
- Strengthen public sector monitoring and inspection systems to include the development of aquaculture products

39. During the review of the identified constraints and opportunities (above), the plenary recognized that most countries were at different stages in their development of aquaculture, and suggested that care should be taken to prioritize the 'steps' according to their individual stages of development. In addition, concerted awareness raising activities on the potential of aquaculture (among policy makers, managers, present and potential stakeholders) were

identified as critical. Continuous awareness rising is also considered important in order to not lose the momentum created by the workshop.

40. The most emphasized issue among the opportunities identified by the plenary was the need for governments to establish clear transparent aquaculture development policies using mechanisms for consultation with other stakeholders (nationally as well as subregionally). Regional co-operation and exchange of experiences and technology was the second most recurrent issue in the opportunities identified by the plenary. The participants also identified a need to focus on an integrated approach to aquaculture development to ensure its role in contributing to food security and agricultural diversification, where applicable and to ensure compliance with international agreements and guidelines.

CONCLUSIONS

41. The representatives of the various countries were the government aquaculture officers. It is expected that their lines of communication with the Ministers responsible for national fisheries sector development, will ensure the transmission of the workshop results to the appropriate level of national decision-making. Further follow-up on the workshop relative to the re-initiated promotion of aquaculture will depend largely on the interest the returning officers will receive from their Ministries. The CARICOM Fisheries Unit representative agreed to follow up on the workshop at regional level, and especially mentioned that the CRFM could take up the task of functioning as a network for collection and dissemination of information on aquaculture in the region.

42. Many of the participants stressed the urgent need for the development of an aquaculture policy framework and requested information on how to get access to FAO technical support specifically for aquaculture; and technology transfer and policy development; some asked about the possibilities of co-operating with countries and institutions in the subregion where aquaculture pilot projects have been successful. Responding to this the FAO officers provided information on the FAO Technical Cooperation Programme and its guidelines for project proposal formulation.

43. At the end of the workshop it was concluded that this initiative to organize a workshop on sustainable aquaculture development, was highly appreciated by the represented countries and that it is of utmost importance to follow up on what was discussed. New insights into the constraints and opportunities related to aquaculture development in the SIDS of the Lesser Antilles have created awareness on which activities to undertake new initiatives can be based.

AGENDA

Monday, 4 November 2002

09.00 AM	Registration
09.30 AM	Opening Ceremony
10.00 AM	<i>Coffee break</i>
10.15 AM	Election of Chairperson and Adoption of Agenda, Introduction of participants
10.30 AM	Discussion of the synthesis of national experiences in aquaculture development in the Lesser Antilles
11.20 AM	The marketing opportunities for aquaculture products in the Lesser Antilles
11.50 AM	The experiences of developing commercial aquaculture in the Lesser Antilles: Case Studies from St Croix, Martinique and Bermuda • The experiences and potential for developing Red Drum (<i>Sciaenops ocellatus</i>) culture in the Lesser Antilles. IFREMER, Martinique
12.30 PM	<i>Lunch</i>
14.30 PM	Case Studies (continued) • Tilapia production for the Lesser Antilles and other resource-limited tropical areas: Cage culture in small ponds, Green water tank culture, and Aquaponics. St Croix, USVI.
15.15 PM	<i>Coffee break</i>
15.30 PM	General discussions on the presentations by participants, with references to individual country experiences
17.00 PM	Adjournment

Tuesday, 5 November 2002

09.00 AM	Case Studies (continued) • The experiences of taking the culturing of scallops to a commercial phase in small islands: Case study of the Calico Scallop in Bermuda: A model for the Lesser Antilles?
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10.15 AM	<i>Coffee break</i>
10.30 AM	Enabling policy framework for the promotion of sustainable commercial aquaculture in the Lesser Antilles
11.15 AM	Discussions on the aquaculture development experiences of each of the participating countries
12.30 PM	<i>Lunch</i>
14.00 PM	Discussions on the aquaculture development experiences of each of the participating countries (continued)
15.45 PM	<i>Coffee break</i>
16.00 PM	Briefing on the formation composition and mode of operation/ deliberations of the working groups or plenary session
17.00 PM	Adjournment

Wednesday, 6 November 2002

09.00 AM	Plenary session discussions on the strategies (steps to take) to develop sustainable aquaculture in the SIDS of the Lesser Antilles
10.30 AM	<i>Coffee break</i>
10.45 AM	Continuation of plenary session
12.30 PM	<i>Lunch</i>
14.30 PM	Plenary session discussions on constraints and opportunities for sustainable aquaculture development in the SIDS of the Lesser Antilles
17.00 PM	Adjournment

Thursday, 7 November 2002

08.30 AM	Plenary discussions to finalize/amend the outcome of the discussions on sustainable aquaculture development in Lesser Antilles
10.00 AM	Approval of first draft workshop report Closing remarks and coffee break

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PART II

NATIONAL AQUACULTURE STATUS REPORTS

The information provided in the following National Reports were provided by country representatives during the workshop. Their publication, herein, does not imply any expression of or opinion on the accuracy, quality or veracity of the said information, by the editors or the FAO.

**NATIONAL REPORT
OF
ANTIGUA AND BARBUDA**

by

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I. GENERAL INFORMATION

Geography and Economy

<i>Area</i>	440 km ²
<i>Length of coastline</i>	153 km
<i>Shelf area</i>	3 568 km ²
<i>Terrain</i>	Antigua - A relatively high south western volcanic portion with a central diagonal plain and a north eastern limestone region Barbuda - A low relatively uniform topography with highlands reaching an elevation of 30 m
<i>Climate</i>	Tropical
<i>Population</i>	59 355 (1991 census) 75,741 (2001 census)
<i>Annual growth rate</i>	16.3% (1991-2001)
<i>Languages</i>	English
<i>Work force</i>	26 753 (1991) 27% Public Sector, 0.03% Agriculture and Fisheries, 17% Hotels and Restaurants, 55.97% rest
<i>Unemployment rate</i>	3% (1991)
<i>GDP</i>	US\$M 669.88 (2000) at market prices
<i>GDP growth rate</i>	0.06% (1992-2000)
<i>GDP per capita</i>	US\$ 9 319.85 (2000) at market prices
<i>Central Budget</i>	US\$ 224 428 478.65 (2002)
<i>Currency unit</i>	Eastern Caribbean Dollar US\$ 1.00 = EC 2.71 (May 2002)
<i>Agriculture</i>	0.4% of GDP at factor cost (2000)

Fisheries Data

Commodity balance (1999)

Fish for direct human consumption	Production	Imports	Exports	Total supply	Per caput supply
	'000 mt live weight				kg/yr
	1.36	2.11	0.055	3.42	48

Estimated employment

Primary sector	987 fishermen and women 46% full-time 54% part-time and subsistence
Secondary sector	30 vendors, 6 boat builders

Gross value of fisheries output (at ex-vessel prices - 1999)

US\$8.1 million

Trade (1999)

Value of imports	US\$ 9.0 million
Value of exports	US\$ 0.5 million

II. STATUS OF AQUACULTURE PRODUCTION

Background

Antigua and Barbuda's earliest attempts in the late 70s, at freshwater aquaculture were in the production of tilapia and catfish but these proved unsuccessful due to the constraints of low rainfall. In the early 1980s, UNDP/FAO Aquaculture Development and Coordination Programme and the Western Central Atlantic Fishery Commission fielded two missions to the region to examine its aquaculture potential. The mission noted that Antigua had "many sheltered bays and suitable adjacent lands for the culture of juvenile snappers and groupers in cages". Also identified was a demand for mariculture for high quality fish, crustaceans and sea moss for local consumption and for export.

In 1985, the Smithsonian Institute, at the request of the Peace Corps and with funding from the US Agency for International Development, chose Antigua as a pilot site for the production of the Caribbean King Crab, *Mithrax spinosissimus*. The area chosen was Nonsuch Bay, in the north eastern portion of the island, and afterward moved to Valley Church in the southwest. The successful adoption of the project was given a good prognosis but due to the high cost of grow out using tanks, and non-acceptance of *Mithrax* as a substitute for lobster, the project did not attract any investment.

Some experimental work was also done on the production of the Spiny lobster, *Panulirus argus*, in the Valley Church area at the same time. Results of this work were never shared with the Fisheries Division.

Other past projects included the culture of sea moss in Barbuda funded by the Canadian International Development and Research Centre. This was a two-year pilot project and though the project showed potential no private investors showed interest. Another project, the Antigua Shrimp Culture was financed by the Eastern Caribbean Mariculture Ltd, USAID,

Bank of Antigua and the Caribbean Food Co-operation. The farm was located at Nonsuch Bay and had a quarantine/nursery laboratory and 6 two hectare grow-out ponds, supported by a 10-hectare reservoir. In 1985, commercial production of shrimp started using *Penaeus vannamei* and *Penaeus monodon*. The output was sold locally but yields were low, 0.36-0.57 metric tonnes per hectare, and there was difficulty in obtaining disease free juveniles (Fisheries Development Plan 2002-2005). The company has since gone out of business in Antigua.

Within the past year there have been about three proposals for aquaculture projects for the production of conch, lobsters, sea urchins, tilapia, sea cucumbers and aquarium fish. These proposals are still in the planning stage.

In the early 1990s there has been the culture of sea moss on an experimental scale by three persons in Antigua, and in 2000 one grower has gone commercial and has the potential to produce 200 lbs dry weight per day. However, due to low demand locally and the inability presently to access regional markets, this potential has not been realized. One other grower produces only for family and village consumption.

Contribution to national fisheries production

This is negligible. In 2000 only 666 lbs was sold valued at US\$ 7 490. This is considered an insignificant contribution to the fisheries sector in the economy.

Species being cultured and the technologies used

The sea moss species cultured were *Eucheuma* and *Gracilaria*. Currently only *Eucheuma* is being grown. The sea moss is grown on lines in a shallow bay. Pieces of the moss are twisted into long lines of nylon rope and after a few weeks the moss is harvested leaving a portion of the moss in the rope for new growth to occur.

III. HANDLING AND MARKETING OF AQUACULTURE PRODUCTS

Processing of aquaculture products locally

Processing of the sea moss into a beverage is carried out by the local investor at his home. The sea moss is also packaged and sold dried.

Social acceptance of aquaculture products locally

Social acceptance of aquaculture products is limited to using the sea moss as a beverage. Local folklore has it that the drink has aphrodisiacal properties so it is drunk mainly by men.

Marketing of aquaculture products locally and externally

Handling and marketing of sea moss is done by the local investor himself and he is presently able to commit funds to tapping the only local market. He however has a website. How many sales this generates is unknown.

IV. EXISTING POLICY, PLANNING & MANAGEMENT OF AQUACULTURE

Government's involvement in aquaculture development

Government's involvement in aquaculture development is mainly advisory and to give subsidies. Proposals are passed on to the Fisheries Division from the Minister for input.

However, there are no trained aquaculturalists on staff. Generally, investors request a lease of government land.

Private sector involvement in aquaculture

All of the project proposals which have been put forward have come from private investors. Most of the investors have been local with additional funds being raised from non-local investors.

Monitoring and regulatory practice for aquaculture activities

Presently there are no monitoring and regulatory practices for aquaculture activities.

Strategy (existing/planned) for future development

The Fisheries Development Plan 1999-2003 recognises the need for mariculture for the following reasons:

- to diversify the narrowly based economy;
- to increase the use of available and not fully utilized natural species;
- to present opportunities for the development of aquaculture suited for small holders/fishermen and private entrepreneurs and multinational companies;
- to increase foreign exchange;
- to reduce fish imports; and
- to re-establish fisheries where over-fishing seems to be taking place.

To be noted, however, is that current fisheries legislation does not provide for “leasing and partitioning” a section of a bay to be used for mariculture projects. Thus far the only type of secure operation would be on land and that would incur high electricity costs. Also, as pointed out above, the Fisheries Division has no one trained in aquaculture. Current fisheries legislation does not address the development of aquaculture.

by

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Geography and Economy

Fisheries Data

Commodity balance (1997)

Fish for direct human consumption	Production	Imports	Exports	Total supply	Per caput supply
	'000 mt live weight				kg/yr
	5.1	2.2	2.6	4.7	16.5

Estimated employment (1995 Fisheries Census)

Primary sector	8 800 full-time
Secondary sector	200 full-time and 100 part-time

Gross value of fisheries output (At ex-vessel prices - 2001)

US\$ 64.8 million

Trade (2001)

Value of imports	Not Available
Value of exports	US\$ 72.3 million

II. STATUS OF AQUACULTURE PRODUCTION

Species cultured and technologies

Inland aquaculture

At present only one (1) facility in operation, Lucayan Aquaculture Company, Freeport Grand Bahamas, producing *Penaeus vannamei* in four (4) hectare size ponds making a total of ten acres in production. Post larvae imported from Central America for growout. Annual yield of 29 486.50 pounds of shrimp marketed during 2001.

Coastal aquaculture

None of the firms mentioned in the section under Coastal Aquaculture are presently operational.

Aquaculture technologies

The Technical Mission established by the Republic of China on Taiwan ceased operation in 1997.

Aquaculture statistics

29 486.50 pounds of Shrimp (*Penaeus vannamei*) were produced in the Bahamas during 2001 with a value of Bds\$ 182 000.00

III. POLICY MAKING, PLANNING AND MANAGEMENT

The Department of Fisheries (DOF), which falls under the Ministry of Agriculture, Fisheries and Local Government (MAF), is responsible for the management of the fishery industry and for the implementation of fisheries policies and developmental objectives. The Department's objectives for fisheries management are:

- to ensure the optimum utilization of the fisheries resources for the benefit of the Bahamian people;
- to promote the development of local fisheries; and
- to improve the technical capabilities and social well-being of the local fisherman.

The Department of Fisheries is divided into four technical units (Research and Development, Resource Management, Resource utilization and Law Enforcement) and one administration unit. Presently the Department has no office dealing exclusively with aquaculture matters, although high priority has been attached to the development of this sector of the fishery industry. The policy of the Government of the Bahamas is not to invest directly into aquaculture production. However, through the regulatory role of the DOF, it promotes the development of aquaculture mainly through technical assistance and incentives (e.g. duty-free concession on imported equipment). The Department of Fisheries is headed by a Director supported by a total staff of about 50, out of which only two have a background in aquaculture training and fieldwork. The above mentioned officers are responsible for all matters related to aquaculture with the Department.

The aquaculture industry is presently not regulated however a draft Aquaculture Act was prepared in 1984 with the assistance of FAO. The Act was prepared at a time when aquaculture in The Bahamas was at an early stage of development, although it would have provided the Government with the legal framework for controlling and directing the development of the industry, it was not introduced as part of the overall fisheries regulations.

In addition to what is stated in the document, there is a renewed interest by the government to develop aquaculture especially in the Family Islands.

Also, aquaculture is regulated under the present Fisheries Resources (Jurisdiction and Conservation) Regulations, 1986.

IV. TECHNICAL CAPABILITIES

Education and training

The College of the Bahamas does offer a marine biology course.

Research

Presently there are no institutions conducting research in aquaculture. Caribbean Marine Research Centre has discontinued the aquaculture research component at their facilities in Lee Stocking Island, Exuma.

Technical assistance and extension

Little government support in terms of technical assistance and extension services has been provided to the private sector operating commercial aquaculture ventures. Although the Department of Fisheries has been encouraging the promotion and development of the industry in the Bahamas through attractive investment conditions (e.g. land and sea areas lease/purchase agreement, duty-free importation of equipment and fish feed, etc.). The shortage of technical staff and the absence of a research/training facility made it almost impossible for the Department to provide technical support to interested parties. However, the Government hopes that the newly completed shrimp culture centre will enable the staff of the DOF to acquire technical experience, particularly in shrimp culture, so that an extension and technical assistance service can be provided to local and foreign investors.

The Government still offers technical support for project development and duty-free concessions for approved projects.

V. POTENTIAL FOR AQUACULTURE DEVELOPMENT

Physical potential

With regard to its natural resources, Bahamas enjoys a number of important advantages, which favour the establishment of aquaculture operations.

The landform is generally acceptable for aquaculture since large areas of level or gently sloping land above the water table occur in many of the islands. Factors which may constrain pond construction are: (i) the insufficient tidal range to permit filling of ponds at high tide and drainage at low tide, and (ii) the composition of land which is almost pure limestone. These constraints could be overcome by using pumps to manage water supply and by constructing lined earthen ponds, which would, however, considerably affect the initial investment cost as well as running expenses of the ponds, respectively.

Freshwater is available in sub-surface lenses ranging from 20-40 metres in depth in the northern Bahamas to 3-12 metres in the drier southern islands. Apart from these freshwater lenses, no rivers and few ponds exist, therefore significantly reducing the possibility of rearing freshwater species on a large commercial scale. Good quality seawater, on the other hand, is available in abundance, either from the surrounding sea or from wells.

In addition to the above resources, the Bahamas is rich in bays and channels of moderate depth (also relatively well protected from surf and storms), where floating culture structures could be installed and maintained.

In summary, it appears that the essential natural resources for marine aquaculture are abundant, while the potential development and expansion of freshwater aquaculture is limited by the lack of large supplies of freshwater.

Species

An increased interest in aquaculture projects is presently being manifested by the private sector. However, most of their attention is directed to the culture of marine shrimp. On the other hand, taking into account a number of geo-physical factors, which determine the possibility of commercial aquaculture activities in The Bahamas, it appears that the potential

exists mainly for mariculture operations. Although research would still be required to improve the culture technology of some species (e.g. dolphin fish, pompano, grouper, snapper, sponges), the culture of other species such as *Gracilaria*, *Eucheuma*, queen conch (the latter for restocking depleted areas) and brine shrimp could be attempted. This is possible as a result of favourable environmental conditions and relatively well known culture technologies applied in other countries around the world (e.g. *Eucheuma* culture in the Philippines).

Finance

To date the Bahamas Development Bank (BDB) has not financed any aquaculture operations, although one loan application was submitted for a project in Freeport. Although the above loan application has not yet been approved, the BNB appears to be willing to support the aquaculture industry at normal commercial rates. So far the Bank has been approached mainly for loans for fishing vessels and processing plants.

VI. FISH HANDLING, PROCESSING AND MARKETING

Most of the products derived from aquaculture practices are presently for the local fresh market and sold mainly to restaurants (shrimp) through a very simple marketing system. However, locally produced shrimp is currently facing a marketing problem as it appears that the market is somewhat monopolized by one company that imports into the country frozen shrimps produced elsewhere in the region. With regard to processing, most of the existing plants efficiently handle and process products derived from the capture marine sector for the export markets. No plant is specifically handling aquaculture products possibly due to the small and unreliable quantities presently produced. However, should the production from aquaculture considerably increase, the present facilities might be willing to purchase the raw material for processing.

VII. CONCLUSIONS AND FUTURE DEVELOPMENTS

Aquaculture in the Bahamas has attracted a number of investors. However, although its large areas of level land, good sources of saltwater, shallow seawater free from pollution, favourable temperature and good export market potential in the United States, it appears that the development of the sector has progressed rather slowly. The reasons, which may have affected the growth of the industry, may have been multiple, possibly including lack of technology; shortage of investment capital; lack of freshwater; and rich capture fishery industry. It seems that the aquaculture sector in the Bahamas, although yet to become an important industry in terms of production output and revenue, has a good developmental potential particularly with regard to mariculture operations.

Aquaculture in the Bahamas seems to be attracting the attention of both local and foreign (mainly from the USA) investors. However, although a number of environmental and socio-economic factors would favour its development, the industry as a whole is still at an early stage of development. In order to further promote and encourage investments in the sector, the following actions should be promoted in the short term:

- formulation of a national aquaculture policy and action plan;
- upgrading the public sector in order to better assist the private sector with regard to information and technical assistance as well as extension services;

- identification of suitable inland and coastal areas for aquaculture projects in terms of their physical characteristics and economic suitability;
- promote and establish links with other countries in the region more advanced in the development of their aquaculture industry; and
- Promote research and information exchange on marine finfish culture utilizing land-based and marine facilities (e.g. tanks, raceways, floating and submerged netcages, etc.).

**NATIONAL REPORT
OF
BARBADOS**

by

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I. GENERAL INFORMATION

Geography and Economy

<i>Area</i>	430 km ²
<i>Length of coastline</i>	90 km (est.)
<i>Shelf area</i>	320 km ² (est.)
<i>Terrain</i>	Flat, rising to a ridge in the centre
<i>Climate</i>	Tropical
<i>Population</i>	267 900 (2000)
<i>Annual growth rate</i>	0.2% (2000)
<i>Language</i>	English
<i>Work force</i>	138 700 (2000)
<i>Unemployment rate</i>	Total: 9.2%, 11.3% female; 7.4% male (2000)
<i>GDP</i>	Bds\$ 4 290 8 million at factor cost; Bds\$ 28.7 million from fishing (2000)
<i>GDP growth rate</i>	3.5% (2000)
<i>GDP per capita</i>	\$ 16 170 (2000)
<i>Central Gov't budget</i>	- NA -
<i>Currency unit</i>	Barbados Dollar US\$ 1.00 = BDS 2.00 (2000)
<i>Agriculture</i>	4.4% of GDP; includes fishing 0.7% (2000) Products - Sugar, food crops
<i>Industry</i>	9% of GDP (2000). Types: food, beverages, textiles, paper, chemicals, fabricated products, pharmaceuticals, rum.
<i>Trade</i>	Exports: \$ 545.7 million (f.o.b., 2000) Imports: \$ 2,312.1 million (c.i.f., 2000)

Fisheries Data

Commodity balance (2000)

Fish for direct human consumption	Production	Imports	Exports	Total supply	Per caput supply
	'000 mt live weight				kg/yr
	3.12	3.4	0.27	6.23	23.3

Estimated employment (2000)

Primary sector	2 200 full-time and part-time fishermen
Secondary sector	3 800 in fisheries related activities - fish vendors, boat-builders, fish processors & fishery administration staff

Gross value of fisheries output (At ex-vessel prices - 2000)

US\$ 7.5 million

Trade (2000)

Value of imports	US\$ 17.5 million
Value of exports	US\$ 2.3 million

II. STATUS OF AQUACULTURE PRODUCTION

Species cultured and technologies

Inland aquaculture

Tilapia

During the early 1980s a pilot tilapia fish farming project was set up at Greenland, St. Andrew by the Fisheries Division with support from USAID. The Nile tilapia *Oreochromis niloticus*, imported from Jamaica was used. The project was aimed at assessing the feasibility of commercially rearing tilapia in the island. This project did not succeed and ended in 1989 due to inadequate water supplies, fish thefts, poor soil quality, lack of security and limited market demand.

In the 1950s, the then Fisheries Officer D. Wiles reportedly introduced *Oreochromis mossambicus* too many of the existing bodies of freshwater on the island. Several private individuals from the 1980's until about 1999 have carried out small-scale freshwater culture in small concrete tanks of local *O. mossambicus*, generally, with little success. These enterprises were typically integrated with small-scale agriculture, (e.g. irrigation of fruit trees, christophene vines, etc.) and production from these facilities amounted to only a few kilograms overall the life of these projects. One aquaculture venture used hybrid, *O. mossambicus* tilapia brood-stock and juveniles imported from Canada to assess the feasibility of intensive tilapia culture in Barbados using a re-circulating water system. The fish were fed an imported catfish ration. This project eventually failed due the high cost of electricity, water and labour.

Shrimps and prawns

Several private sector proposals to raise fresh water prawns and shrimps have been drawn up, but none have gone beyond the project formulation stages.

Coastal culture (mariculture)

Seamoss

Consett Bay is one of the few areas in Barbados where there is a protected bay suitable for seamoss farming. A project to culture sea moss was conducted by Government and fisherfolk from the Consett Bay area during the period February and March 1996. The seed species used was (*Gracilaria* sp.) imported from St. Lucia. It grew rapidly for about six weeks before suddenly disappearing from the long lines on which it had grown, reportedly having been stolen. In 1998 efforts were made to encourage fishers from the area to recommence culturing sea moss at Consett Bay. By December 1998 about 200 pounds (wet weight) was harvested from four PVC rafts. No sea moss has been cultured at this site since February 1999. The cessation of the activities is attributed to lack of interest on the part of the fishers involved, who do not seem inclined to assume the role of farmers. However, it has been demonstrated that this location can be used for seamoss farming, if motivated individuals can be found to culture the plants.

One private individual also started to cultivate *Gracilaria* species in 1996 at Half Moon Fort on the Northwest of the island. He progressed from using long-lines, to several designs of PVC rafts. The final design used commercially was 10 x 10 feet square and 1.5 feet deep with the sides and bottom covered with netting to prevent grazing by reef fish. The operator reported production figures of about 1800 and 700 pounds (dry weight) for 1998 and 1999 respectively. He started in 1998 with twenty (20) rafts and by the end of the year had increased the number of rafts to thirty-five (35). His level of production for 1998 varied between 40-60 pounds of dry seamoss per week. Each raft was reported to produce about 10 pounds of dried seamoss per harvest. This project was scaled down from mid 1999 after the operator could no longer find any one willing to work on the farm and he has since ceased production entirely.

An interesting fact concerning the mariculture of *Gracilaria* species at both of the sites mentioned was that thousands of juvenile lobsters were often found settled in the growing moss. This suggests that there is a potential for lobster mariculture enterprises in conjunction with seamoss culture.

Finfish

The rearing of the dolphin fish or mahi mahi (*Coryphaena hippurus*) was started by a private enterprise (Caribbean Aqua Farms) in November 1994. Juveniles were imported from Florida and stocked in offshore cages off Half Moon Fort, St. Lucy. The fish did not thrive and end production was very low. In 1997, mariculture activities at this facility were mainly related to the importation of fertilized dolphin eggs for hatching. However, this did not prove to be successful due to high larval mortality. Attempts were also made with little success to get dolphin captured around Barbados to spawn in captivity onshore. During 1998 this facility was basically inactive. Mariculture activities recommenced in mid 1999 under new management and red drum, (*Sciaenops ocellatus*) were cultured. The fertilized eggs were imported from Martinique and hatched out in an onshore hatchery. Juveniles were later stocked in the offshore sea cages for grow-out with some success. However, by June 2001, this project was winding down for repairs to the facilities and has been basically inactive since the end of 2001.

No coastal or inland aquaculture activities of note are currently being undertaken in Barbados.

III. POLICY MAKING, PLANNING AND MANAGEMENT

It is proposed to include aquaculture regulations among the suite of fisheries regulations to be introduced in the near future. The regulations will set out the requirements for aquaculture enterprises with emphasis on environmental management.

The Barbados Aquaculture Association was formed in 1991 under the umbrella of the Barbados Agricultural Society aimed at being a focal point for public and private sector interests in aquaculture sector development. However, its main role was never defined and the association has not been active in aquaculture related activities.

IV. TECHNICAL CAPABILITIES

Education and training

An aquaculture research centre was opened at the University of the West Indies (UWI), Cave Hill in 1987. One doctoral (PhD) student worked on tilapia larval production and rearing activities. This work has since been completed. The building is no longer used for aquaculture purposes and no one is currently actively involved in aquaculture research anywhere in the island.

The Caribbean Conservation Association continues to promote programmes aimed at formulating and implementing solutions to environmental problems. It also seeks to provide consultancy services related to natural resource development as well as to implementing natural resource projects.

Research

As mentioned earlier, an aquaculture project was established at the Greenland Agricultural Station in 1983 and lasted until 1989. The 0.63 acres of ponds and a hatchery are no longer used for applied aquaculture research. The Fisheries Division is not presently in a position to carry out any applied aquaculture research due to lack of facilities and trained personnel.

Technical assistance and extension

The Fisheries Division's technical assistance and extension activities are confined to providing available information to persons interested in aquaculture and monitoring the activities of aquaculture operations. UWI no longer provides technical support, but the former Ph.D. student continues to offer advice on an ad hoc basis to interested persons. The Analytical Services Laboratory can assist with the analysis of soil and water samples.

V. POTENTIAL FOR AQUACULTURE DEVELOPMENT

Physical potential

The development of aquaculture in Barbados would certainly be aided by the favourable tropical condition, which includes a high temperature and salinity stability all year round. However, other factors severely limit these developmental possibilities.

With regard to the land, it has been shown that the limited supply of both freshwater and suitable soil types is a major constraint to the development of fish farming in Barbados at a significant scale. The permeable nature of coral rock, which forms 86% of the island, allows water to percolate into the soil thus reducing surface run-off, especially during the dry season, and the formation of significant freshwater bodies. The dearth of bodies of surface water is therefore a main constraint on inland aquaculture development. Nevertheless, with agreement from Barbados Water Authority, ground water could be pumped to the surface and used for fish rearing. Presently, a great number of private wells exist on the island for agriculture irrigation, and the association of agriculture and aquaculture activities could offer a more rational use of the pumped water.

Even artificial ponds cannot be cheaply constructed at most areas around the island due to the porous nature of the coral rock-cap. This is a major factor limiting the development of inland aquaculture activities. Only two main areas with appropriate soil characteristics have been identified in the country where artificial ponds can be dug. They are the Scotland District and in St. George Valley, in the northern and central parts of the island, respectively. The two areas have various patches of clay, silt-clay and sand-clay layers, variable, however, in depth, soil plasticity and permeability.

With regard to the coastline, various sides of the islands have specific and predominant characteristics. The East Coast is exposed to wind driven currents and strong wave action. Coral reef development along this coast is generally poor, with only a few patches. There is a high degree of urbanization in the southern part of the coast. Cliffs with a few small bays characterise the eastern coastline in both the southern and northern quadrants. The west and south coasts, despite being the most protected areas and potentially the most suitable for mariculture are highly urbanized and cater mainly for the important tourism industry.

Species

Such unfavourable geographical conditions seriously limit the type of aquaculture and the species that can be reared. The commercial culture of marine finfish and shrimp on a large-scale are unlikely to develop due to the absence of suitable physical resources (land space, lagoons, and protected bays). The development of submergible marine netcages could be the only alternative although it would be extremely costly and technically demanding due to the exposure of the coastline and narrowness of the continental shelf.

Taking into account the physical factors, which greatly determine the possibility of commercial aquaculture development in Barbados, the limited potential exists for the following types of culture:

- bivalve culture along the south and west coast;

- rearing of juvenile queen conch (*Strombus gigas*) for reseeding of shallow water areas;
- seamoss (*Gracilaria* spp.) cultivation using long-lines;
- culture of indigenous ornamental fish species;
- culture of the Asian freshwater prawn in land-based concrete tanks;
- culture of tilapia in land-based concrete tanks; and
- red drum (*Sciaenops ocellatus*) and dolphin fish culture in sea cages.

VI. CONCLUSIONS AND FUTURE DEVELOPMENTS

It should also be noted that Barbadian consumers prefer marine fish. Introducing freshwater fish, shellfish and even non-native marine fish to the local market will only be commercially successful if accompanied by an intensive promotion effort. Therefore, any aquaculture enterprise in Barbados will have to factor in the costs of marketing their produce.

**NATIONAL REPORT
OF
THE COMMONWEALTH OF DOMINICA**

by

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I. GENERAL INFORMATION

Geography and Economy

<i>Area</i>	754 km ²
<i>Length of coastline</i>	152.93 km
<i>Shelf area</i>	716.45 km ²
<i>Terrain</i>	Mountainous volcanic island with rain forest cover
<i>Climate</i>	Tropical
<i>Population</i>	81 200 (1988 est.)
<i>Annual growth rate</i>	0.3%
<i>Languages</i>	English (official); French patois is widely spoken
<i>Work force</i>	43 000 (1988) - Agriculture 37%, Services 30%, Industry and Commerce 20%
<i>Unemployment rate</i>	10% (1988)
<i>GDP</i>	US\$ 114 million (1988)
<i>GDP growth rate</i>	5.6% (1988)
<i>GDP per capita</i>	US\$ 1 650 (1988)
<i>Central Gov't Bndget</i>	US\$ 40 million (1998)
<i>Currency unit</i>	Eastern Caribbean Dollar US\$ 1.00 = ECS 2.71 (May 2002)
<i>Agriculture</i>	Products: bananas, citrus, coconuts, cocoa, essential oils.
<i>Industry</i>	Types: agricultural processing, soap and other coconut based products, apparel, cigars
<i>Trade</i>	Exports: US\$ 55.5 million (1988) - bananas, citrus, fruits, soap, cocoa. Imports: US\$ 87.5 million (1998) - machinery and equipment, foodstuff, manufactured articles, cement.

Fisheries Data

Commodity balance (2000)

Fish for direct human consumption	Production	Imports	Exports	Total supply	Per caput supply
	'000 mt live weight				kg/yr
	1.15	0.67	0.00	1.82	22.20

Estimated employment (1983)

Primary sector	An estimated 2 000 part-time and full-time fishermen
Secondary sector	Not Available

Gross value of fisheries output (at ex-vessel prices - 2000)

US\$ 2.4 million

Trade (2000)

Value of imports	US\$ 1.58 million
Value of exports	Negligible

II. STATUS OF AQUACULTURE PRODUCTION

Species cultured and technologies

Inland aquaculture

Currently, the Asian freshwater giant prawn, *Macrobrachium rosenbergii* is the only species being cultured in Dominica. With regard to the existing level of operations, there are four private farms in operation.

All of the freshwater prawn post-larvae are produced at the Government-owned Prawn Experimental Farm in Belfast. The infrastructure of the station was completed in 1984 and the first stock of post-larvae was obtained from Guadeloupe and introduced into the grow-out ponds in late 1985. Two years later the facility was further expanded to include a clear water hatchery system set-up with funds and technical assistance of Taiwan (Province of China) through the Taiwanese Agriculture Cooperation Mission.

Coastal aquaculture

Due to the topography of the country, with its steep coastline, limited sites are available for coastal aquaculture. At the present moment, the indigenous population of seamoss (*Gracilaria* sp.), which is found throughout the island, is popularly harvested for human consumption as a drink or in a jelly form. However, due to over-exploitation of the natural stocks, the Fisheries Division has included in its National Fishery Sector Plan for the period 1992-93, the initiative of culturing the seaweed utilizing the technology developed in Saint Lucia, i.e. bamboo rafts and/or long-line culture method.

Aquaculture technologies

The Agricultural Mission of Taiwan (Province of China) constructed a marine hatchery at Canefield and began growing tilapia in saltwater but the mission closed the facility in 1998.

The physical structures remain, with tilapia in the concrete ponds, but no aquaculture activities occur on that site today.

With regard to the Asian freshwater giant prawn (*Macrobrachium* sp.), the Fisheries Division feels that the available technology ranks to acceptable world standards, particularly when considering the level of post-larvae survival. However, the refinement of the on-growing technology is presently affected by the lack of facilities and technical experience, particularly in the field of nutrition.

Coastal aquaculture (mariculture) has been attempted on a number of occasions to grow seaweed (*Gracilaria* sp.) in sufficient quantities to supply two local beverage manufacturers. The quantities demanded were never produced so the beverage manufacturers have to import some of the raw materials (dried seaweed) from other neighbouring islands. The local beverage manufacturers are planning to employ persons to increase local production, but the problem of larceny is a major concern.

A project to propagate hard and soft corals using local species for export and reef restoration was granted a license in 1998. The licensee attempted to export a shipment of stony corals which is listed on CITES Appendix II. The shipment was confiscated in the US, so only soft corals can be exported at present. Some propagation of hard corals continues but this is focussed on the restoration of degraded areas within the Cabrits Marine Park.

Aquaculture statistics

Reliable production statistics are not available. Bearing in mind the present number and size of the operations, a combined output estimate of the *Macrobrachium* species can be placed in the range of a couple of thousand kilogrammes. No accurate data is also available for seaweed collected from the wild stocks.

III. POLICY MAKING, PLANNING AND MANAGEMENT

The Fisheries Division (FD) of the Ministry of Agriculture, Lands, Fisheries and Forestry (MALFF) is the government office responsible for aquaculture policy making and for the co-ordination of all planning in this sector of the fisheries industry. The main objectives of the FD concerning aquaculture development are:

- to complement the supply from the marine capture fishery and therefore increase protein intake;
- to reduce expense of foreign exchange by cutting down in fish imports;
- to create employment;
- to promote agriculture diversification by making use of marginal agriculture land and resources;
- to promote conservation of natural resources (wild and indigenous stocks); and
- to increase overall socio-economic status of the people.

The FD is made up of five units including the Aquaculture Unit.

The aquaculture activities of the public sector have declined since 1996 when the experimental hatchery was handed over to the agricultural mission of the Taiwan (Province of China). No official records or information on the activities are available from that facility.

In addition to the ordinary legislation related to land tenure, sanitary regulation, etc., the only specific reference to aquaculture is made in the Fisheries Act No. 11/1987; the specific reference relating to aquaculture provides for the leasing of seabed areas to persons interested in aquaculture development. The Act can be deemed to be complemented by a series of laws issued by other ministries, such as the Ministries of Health and the Environment.

IV. TECHNICAL CAPABILITIES

Education and training

No academic institutions exist in Dominica where education and training in aquaculture related subjects could be obtained. Formal academic education can, however, be obtained at the University of West Indies (UWI) either in the Campus of Cave Hill in Barbados, Mona Campus in Jamaica and in the Campus of St. Augustine in Trinidad and Tobago, although a specific programme in aquaculture is not available. The UWI has an exclusive liaison centre on the island.

There is need for trained aquaculturists if fully commercial ventures are to be developed. The Government of Dominica although not providing technical assistance and extension service to farmers interested in the aquaculture has supportive of prawn culture. This is the result of a greater interest manifested by the private sector due to the higher market price and demand of prawn compared to the tilapia.

Research

The only facility available to the public sector is closed; there are no active aquaculture research activities at the present time.

Technical assistance and extension

The Fisheries Division provides as much support as possible to the private sector with regard to advice and extension. The support provided to interested investors and existing farmers include (i) land survey for site suitability, (ii) technical assistance for pond construction and water management and (iii) facilitating the supply of prawn post-larvae free of import duties or at subsidized cost.

V. POTENTIAL FOR AQUACULTURE DEVELOPMENT

Physical potential

Although the island of Dominica is of volcanic origin and characterized by a rugged landscape, suitable sites are reasonably available for inland aquaculture development, where small-scale operations (earth ponds) can be established. With regard to surface freshwater, it is abundantly available throughout the island and therefore not a limiting factor.

An overall land survey of the country, for the identification of suitable sites for aquaculture development, has been carried out in the recent past mainly with regard to land morphology and water availability. The Fisheries Division, however, feels that an additional survey is required taking into account other important factors such as land geology (i.e. soil type), land ownership, and availability of infrastructures (roads, electricity and other services). Development of coastal aquaculture, although possibly achievable in certain areas and by

using certain culture techniques (e.g. long-lines), has generally not been attempted because of the exposed coastlines.

Species

In spite of the availability of the country's natural resources, land topography/morphology, available technologies and present market demand, the only aquaculture development existing in today Dominica is semi-commercial for the following types of culture:

- freshwater pond culture of *M. rosenbergii* (prawn) species; and
- mariculture of seamoss (*Gracilaria* spp.) using long-lines and/or floating rafts.

Loans for farmers interested in commercial aquaculture operations can be obtained either from the National Commercial Bank (a semi-government institution) and the Agricultural Industrial Development Bank (AIDB) under the Ministry of Development. The AIDB has established a main credit line of US\$ 1 million for the development of the fishery and aquaculture industry, which however has been underutilized. The loans available through the above mentioned banks are offered at an annual interest rate of 11.5 and 17% per year.

VI. FISH HANDLING, PROCESSING AND MARKETING

At present, production from aquaculture operations (as most of the catch from the capture fishery) is sold fresh either in the vicinity of the culture sites or in small outlets in the major inhabited centres. Freshwater prawns are usually graded according to size and mainly sold directly to hotels and restaurants. Previously there was a grading system and government sale prices were as follows:

- | | | |
|--------------------|-----------------|----------------|
| • Grade A (Large) | 13-17 prawns/kg | @ US\$ 5.8 /kg |
| • Grade B (Medium) | 26-35 prawns/kg | @ US\$ 5.2/kg |
| • Grade C (Small) | 35-53 prawns/kg | @ US\$ 4.7/kg |

The prices are presently averaging US\$ 13.25 per kilogram. Once the private sector started producing the prawn with severely reduced production subsidy costs became higher and consequently the increase in the retail prices of the product.

VII. CONCLUSIONS AND FUTURE DEVELOPMENTS

Within the limits of freshwater and coastal aquaculture development in Dominica, the Government, through the Fisheries Division, remains committed to the promoting the development aquaculture in the country.

**NATIONAL REPORT
OF
GRENADA**

by

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I. GENERAL INFORMATION

Geography and Economy

<i>Area</i>	344 km ²
<i>Length of coastline</i>	121 km
<i>Shelf area</i>	3 100 km ²
<i>Terrain</i>	Volcanic in origin, with interior dominated by mountain peaks, steep ridges, and deep narrow valleys.
<i>Highest peak</i>	Mount St. Catherine - 833 m
<i>Climate</i>	Tropical
<i>Population</i>	100 703 (1999 est.)
<i>Annual growth rate</i>	0.45%
<i>Languages</i>	English (official); some vestigial French patois
<i>Work force</i>	42 250 (22 679 male; 19 571 female) - Agriculture 33%, Industry 17%, Other 50%
<i>Unemployment rate</i>	17% (1996); 10.3% male, 24.8% female
<i>GDP</i>	US\$ 243 million at factor cost in constant prices (1999)
<i>GDP growth rate</i>	7.51% (1999)
<i>GDP per capita</i>	US\$ 2 413 (1999)
<i>Central Gov't Budget</i>	US\$ 89.8 million (1999)
<i>Currency unit</i>	Eastern Caribbean Dollar US\$ 1.00 = ECS 2.71 (May 2002)
<i>Agriculture</i>	10% of GDP (1999). Products: nutmeg, mace, cocoa, bananas, fruits, vegetables.
<i>Industry</i>	22.23% of GDP (1997). Types: Manufacturing (5.4%) (7.03%), hotel/restaurant (7.87%), construction (7.33%)
<i>Trade</i>	Exports: US\$ 42 million (1998) - nutmeg, mace, cocoa, bananas, fruits, vegetables, clothing. Imports: US\$ 206 million (1998) - food, machinery and transport, manufactured goods, fuel.

Fisheries Data

Commodity balance (2000):

Fish for direct human consumption	Production	Imports	Exports	Total supply	Per caput supply
	'000 mt live weight				kg/yr
	1.70	0.44	0.54	1.60	16.0

Estimated employment (2000)

Primary sector	An estimated 1749 fishermen, 85% full-time, 15% part-time and subsistence
Secondary sector	100 vendors, 20 boat builders

Gross value of fisheries output (at ex-vessel prices - 2000)

US\$ 2.64 million

Trade (2000)

Value of imports	US\$ 1.5 million
Value of exports	US\$ 2.64 million

II. STATUS OF AQUACULTURE PRODUCTION

Species cultured and technologies

Inland aquaculture

Inland aquaculture in Grenada is currently carried out on a limited scale. In 1982 some *Oreochromis niloticus* were released in selected rivers and ponds in the northeast and western regions of the island, but this only resulted in subsistence activities. In the late 80s, a pond culture project on the Asian giant freshwater prawn (*Macrobrachium rosenbergii*) was funded by the Organization of American States (OAS) and operated by the Grenada Science and Technology Council. Although encouraging results were obtained from the pilot project and some interest stimulated among the private sector, there were practically no follow-up activities either from the Government or the private sector. In 1992 a pilot project (funded by the Peoples Republic of China - Taiwan), was established to produce fresh water juvenile prawns (*M. rosenbergii*), to farmers. It consists of a hatchery and grow-out ponds, and five farmers were assisted by Government to construct ponds, while several more showed interest in its farming. Tilapia (*Oreochromis mossambicus*) was also cultured. However, when the technical assistance from Taiwan ceased in 2000/2001, operations at the project were severely affected due to lack of adequate funding, and Government has since commercialized on a lease basis, operations at the facility, where salt water shrimp is produced.

Coastal aquaculture

Attempts in culturing seamoss (*Gracilaria* sp.) were carried out by the Artisanal Fisheries Development Project in the mid-80s with financial support from the International Fund for Agriculture Development (IFAD). Although encouraging results were obtained, no commercial operations were established due to the selection of unsuitable culture sites and theft of the culture rafts.

During the same period, a Caribbean king crab (*Mithrax spinosissimus*) culture research project, financed by a private investor, was underway in the island of Carriacou. The project was eventually abandoned due to financial difficulties of the investor.

Aquaculture technologies

The aquaculture technology available in Grenada is limited to the culture of seamoss. Some experience in the culture of the freshwater prawn is also locally available. However, most of the know-how is limited to one skilled staff of the Fisheries Division. Therefore, in order for the country to develop its limited potential, applied and adaptive research are needed to develop simple technologies suitable for the local environmental and socio-economic conditions.

Aquaculture statistics

Up until 2001, approximately 0.5 metric tons of aquaculture products were produced. Approximately 80% were fresh water prawns (*M. rosenbergii*), and 20% Tilapia (*O. mossambicus*). However, production has since declined. However, with the commercialisation of the aquaculture facility, production is expected to increase in the near future, although not significantly since the facility is limited in land space for pond construction. It seems, however, that the on-going development in many neighbouring countries would stimulate interest in the public sector to promote and assist the development of a local industry.

III. POLICY MAKING, PLANNING AND MANAGEMENT

The Fisheries Division (FD) of the Ministry of Agriculture, Lands, Forestry and Fisheries (MALFF) is the government office responsible for aquaculture policy making, planning and co-ordination of all developmental efforts directed towards the sector. Only one staff member of the Fisheries Resource Unit has some experience in aquaculture having received two years training in aquaculture in Cuba, as well as having participated in three short training courses in seamoss culture in St. Lucia, and freshwater prawn culture in Taiwan and Jamaica.

One of the specific objectives of the Unit is to develop an aquaculture and freshwater resources assessment programme. However, although the above objective has been highlighted from 1992 in the Operational Plans of the Fisheries Division, no funding has been allocated to the programme, due to the limited funds available to the Fisheries Division.

The aquaculture sector is presently not receiving much attention nor emphasis compared to the capture fishery sector, although the Government is seeking and welcomes external support to establish aquaculture projects aimed at developing and promoting the sector as an option to the capture fishery and use of marginal agricultural land.

Apart from legislation related to land tenure, use of inland waters, sanitary regulations, etc., the only specific reference to aquaculture is made in the Fisheries Act No. 15/1986 dealing with leasing of sea areas for mariculture activities (e.g. seaweed culture).

IV. TECHNICAL CAPABILITIES

Education and training

One academic institution (St. Georges University) exists in Grenada where education and training in marine biology or related subjects such as aquaculture can be obtained. Formal education, specific to aquaculture, can also be obtained at the St. Augustine campus of the University of West Indies in Trinidad and Tobago.

Research

Currently, the only public facility available is the aquaculture facility provided by the Government of Taiwan, which produced mainly freshwater prawns and tilapia to a lesser extent. However, the facility is now commercialised and special arrangement must be negotiated with the private owners to use the facility for research purposes.

Technical assistance and extension

Due to the shortage of staff, budget constraints and lack of any research/training facilities, the Fisheries Division has been unable to provide the necessary technical assistance to farmers who expressed keen interest in aquaculture.

V. POTENTIAL FOR AQUACULTURE DEVELOPMENT

Physical potential

Grenada is a volcanic island characterized by a mountain ridge (highest peak: 840 m) that forms a spine throughout the length of the island. The centre of the island is covered by a relatively thick rain forest. With regard to the coastline, various sides of the island have specific and predominant characteristics. The west coast is dominated by steep cliffs alternated with rather small flat rivers outlets usually few centimetres above the mean sea level. Flat alluvial plains on the other hand dominate the northeast coast, while the southeast coast is characterized by a number of large protected bays usually associated with river outlets and alluvial platforms.

The climate of the island is typically tropical with a mild dry season lasting from January to May. The rest of the year the weather remains rather wet with a mean temperature ranging between 30-32°C. Rainfall varies from 1 500 mm/year in the coastal areas to about 4 000-6 000 mm/year in the mountains.

The favourable tropical conditions of the island (high temperature and salinity stability all year round) and the good quality of the inland (freshwater) and coastal (seawater) waters would certainly aid aquaculture development in Grenada. However, the potential developmental degree of the sector is likely to be limited by the availability of land.

According to the findings of a FAO technical mission to Grenada in 1986, approximately 100 hectares of flat lands have been identified as suitable for aquaculture operations, most of that is located along the north-eastern coast. The above-mentioned land, however, belongs to private farmers and therefore a number of socio-economic constraints may additionally hinder the development of the industry.

Species

Although a number of technical and socio-economic factors could favour the development of aquaculture in Grenada, such as the good water quality, availability of freshwater supply by gravity, relatively cheap labour cost and the possibility of incentives for private investors, others seriously limit the development potential of the industry. Among the limiting technical factors are the lack of skilled staff, low concentration of wild fry of high value species (e.g. groupers and marine shrimps), and the limited availability of suitably large coastal areas. The high energy cost, the present situation of the banking system and the lack of capital on the other hand are some of the economic factors which will likely hamper the development of aquaculture particularly at the level of small owners. A limited potential, however, does exist for the following types of culture:

- seamoss (*Gracilaria* spp.) cultivation using long-lines and/or floating rafts; and
- culture of the Asian freshwater prawn (*M. rosenbergii*) and tilapia in earth ponds;

Finance

The Grenada Development Bank (GDB) is the only government financing institution that provides loans to fishermen at an interest rate ranging between 8-9% instead of 11.5% charged by other commercial banks. However, although the same rate conditions would be applied to farmers interested in developing aquaculture projects, so far the bank has yet to receive any loan requests for such projects.

VI. FISH HANDLING, PROCESSING AND MARKETING

The fish catch in Grenada is distinctly for the fresh fish market. There are presently eight market centres and one central facility in St. George equipped with blast freezers, chillers, etc. Seasonal supply continues to affect the consistent availability of fish on the local market. With specific regard to species, which could be cultured locally, handling and processing would not cause serious problems if the production were for the local market. Factors which would certainly facilitate the handling and processing aspects of the industry are: (i) small size of the country and therefore a rapid transportation of the products from one site to another, and (ii) the products would be mainly, if not totally, for the fresh market. However, in order to encourage the development of the industry other marketing and economic aspects need to be seriously analysed and considered prior to investing in any particular project. Some of the aspects, which should receive due consideration, are market acceptability of the product (e.g. tilapia) and production costs.

VII. CONCLUSIONS AND FUTURE DEVELOPMENTS

Aquaculture in Grenada is not a developmental priority if compared to the capture fishery sector. However, it appears that the Government, although financially unable to channel

much effort towards the development of the industry, is willing to support international and regional activities aimed at promoting the sector. To date the aquaculture industry as a whole is still at a very early stage of development. Finally, the country would be willing to collaborate closely and exchange information with neighbouring countries, most of which already have some kind of research/training facility.

Considering the past actions carried out by the Fisheries Division such as the FAO Aquaculture Feasibility Study in Grenada in 1986 (TCP/GRN/6651), and the hatchery funded by Taiwan (Province of China), the short and medium-term priorities aimed at strengthening and supporting the role of the FD in promoting aquaculture development seem to be the following:

- upgrading of the public sector in order to better acquire the capacity to assist the private sector with regard to both technical assistance and extension services;
- detailed identification of suitable areas for land-based and coastal aquaculture operations with regard to their physical and socio-economic suitability; and
- provide technical assistance and training to revitalize and continue the projects on seamoss, king crab and freshwater prawn culture.

**NATIONAL REPORT
OF
SAINT KITTS AND NEVIS**

by

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I. GENERAL INFORMATION

Geography and Economy

<i>Area</i>	269 km ²
<i>Length of coastline</i>	135 km
<i>Shelf area</i>	690 km ²
<i>Terrain</i>	Volcanic islands with central mountainous forest
<i>Climate</i>	Tropical maritime
<i>Population</i>	45 900 (2000 est.)
<i>Annual growth rate</i>	0.3 % (2000)
<i>Language</i>	English
<i>Work force</i>	22 583
<i>Unemployment rate</i>	4.8 % (2000 est.)
<i>GDP</i>	US\$ 349.4 Million (2000)
<i>GDP growth rate</i>	4%
<i>GDP per capita</i>	US\$ 7 471 (2000)
<i>Central Gov't budget</i>	US\$ 110 764 000 (2000)
<i>Currency unit</i>	Eastern Caribbean Dollar US\$ 1.00 = ECS 2.71 (May 2002)
<i>Agriculture</i>	Agro-Products: Sugar, Vegetables, fruits, fish, livestock, 4.5% + (fishing: 1.7%)
<i>Industry</i>	Trans./comm.: 18%, Manufacturing: 11.6%, Construction: 14%, Hospitality: 7%, Banking/financial: 13%
<i>Trade</i>	Exports: \$ 50.78 million - Sugar, rum, molasses, electronic/electrical components, miscellaneous manufactured goods Imports: \$ 172 563 million - Machinery, electrical items, foodstuff, garments, fuel-oils, transportation equipment, agro-chemicals, fertilizer & pesticides, beverages, miscellaneous consumer goods & materials

Fisheries Data

Commodity balance (2000)

Fish for direct human consumption	Production	Imports	Exports	Total supply	Per caput supply
	'000 mt live weight				kg/yr
	0.470	1.376	0.073	1.846	43.9

Estimated employment (2000)

Primary sector	578
Secondary sector	Not Available

Gross value of fisheries output (at ex-vessel prices)

Not Available

Trade (2000)

Value of imports	US\$ 2.81 million
Value of exports	US\$ 0.245 million

II. STATUS OF AQUACULTURE PRODUCTION

Over the last two decades aquaculture has been thought of as supplemental provider of fresh fish for the country. A number of attempts have been made at developing viable systems within both islands.

In Saint Kitts, a marine shrimp farm was attempted using a natural salt pond. This encountered a number of technical problems. The venture was later abandoned. The farm produced a small amount of the shrimp that was marketed locally.

On Nevis, attempts were made through assistance from the OAS to develop a tilapia project. However, this venture encountered a number of challenges both financial and technical. In spite of the challenges, one of the project's main objectives was achieved. This was the awareness of the local population of the potential for aquaculture. This was evident as a number of persons expressed their interest in starting their own backyard production. One of those persons was the former Premier of Nevis. Today concerns are being raised by the Fisheries Department, as a number of ponds/water catchments that were stocked with tilapia are being harvested indiscriminately by locals. Aquaculture still does not make any contribution to the national statistics of fish production.

Handling and marketing of aquaculture products

Presently, nothing is being cultured. However, different varieties of tilapia can be found both on Saint Kitts and Nevis in water catchments and back yard systems. Experience has demonstrated that aquaculture products can be successfully marketed on Saint Kitts and Nevis. Shrimps were marketed whole and headless with much success.

III. POLICY MAKING, PLANNING AND MANAGEMENT

The future of aquaculture looks hopeful. It is anticipated that with more lands becoming available, as a result of adjustments in the present acreage under sugar cane production, aquaculture could get the long awaited boost. Ironically, in the Department of Agriculture "Landscape after Sugar", little or nothing has been said as to the potential for aquaculture to influence land use. Nevertheless, the Government has stated its intention to develop aquaculture and a number of avenues are being pursued to achieve this goal.

It is suggested that any significant development in aquaculture will come through the private sector with government providing an enabling environment for development. A number of proposals have already been received. On Saint Kitts, one proposal to "grow out" tilapia is currently under way. No brood stocks or nursery will be run. While on Nevis plans are being developed to commence a multi-million dollar aquaculture project. Not much information is available on this proposal.

With regard to legislation, very little is legislated with direct reference to aquaculture. The Fisheries Management Unit has been mandated by the Ministry of Agriculture to develop projects for aquaculture. The process is still in its infancy.

**NATIONAL REPORT
OF
SAINT LUCIA**

by

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I. GENERAL INFORMATION

Geography and Economy

<i>Area</i>	616 km ²
<i>Length of Coastline</i>	130 km
<i>Shelf area</i>	522 km ²
<i>Terrain</i>	Mountainous
<i>Climate</i>	Tropical maritime
<i>Population</i>	158 018 (2001)
<i>Annual growth rate</i>	1.47% (2000)
<i>Language</i>	English (official); French patois is common throughout the country.
<i>Work force</i>	Agriculture 36.6%, Industry and Commerce 20.1%, Services 18.1%.
<i>Unemployment rate</i>	18%
<i>GDP</i>	US\$ 584.3 million (2002)
<i>GDP growth rate</i>	4.05% (2001)
<i>GDP per Capital</i>	US\$ 2 823 (1999)
<i>Central Govn't Budget</i>	ECS 492 814 068 (2002/2003)
<i>Currency Unit</i>	Eastern Caribbean Dollar US\$ 1.00 = ECS 2.71 (May 2002)
<i>Agriculture</i>	6.3% of GDP (2001). Products: bananas (major), other crops, livestock, fishing, forestry.
<i>Industry</i>	4.9% of GDP (2001). Types: garments, electronic components, beverage, corrugated boxes.
<i>Trade</i>	Exports: US\$ 43.8 million (2000) - bananas, other Agricultural products, oil and fats, manufactured goods. Imports: US\$ 359 million (2000) - food, fuel, manufactured goods, machinery and transport equipment.

Fisheries Data

Commodity balance (1989)

Fish for direct human consumption	Production	Imports	Exports	Total supply	Per caput supply
	'000 mt live weight				kg/yr
	1.90	0.70	0.0	1.60	10.60

Estimated employment (2001)

Primary Sector	An estimated 2096 fishermen half of which are full-time
Secondary Sector	Not Available

Estimated fish production (2001)

1 967.2 tonnes

Gross value of fisheries Output (at ex-vessel prices - 2001)

SS 8.6 million

Trade (2001)

Value of imports	ECS 232 790 706.00
Value of exports	ECS 33 972 456.00

II. STATUS OF AQUACULTURE AND PRODUCTION

Species cultured and technologies

Inland aquaculture

The Asian freshwater prawn *Macrobrachium rosenbergii*, the Nile Tilapia (*Oreochromis niloticus*), and the Red Hybrid Tilapia are the three species cultured in Saint Lucia. The culture of both the freshwater prawn and the tilapia are carried out in small earthen ponds ranging between a few hundred square metres to a couple thousand. The ponds are usually fed by a continuous flow of pumped freshwater or gravitational flow from water dams fed by rivers or springs. The overall combined surface area under present production for both species has been estimated around 24 800 square metres. The private sector interest in freshwater aquaculture, particularly with regard to freshwater prawn farming, is steadily increasing as clearly shown by the recent increase in pond areas.

Coastal aquaculture

The only marine species which has received considerable attention and currently being cultured using a simple technology is a local strain of seamoss known as GT (*Gracilaria* sp.). The seamoss was originally carried out on floating bamboo rafts, which have been replaced since 1990 by the long-line method mainly due to its stronger resistance to wave action. The long-lines are made of polypropylene, 0.75-1 cm in diameter by 10-20 m long, suspended by used oil bottles and kept in position with concrete or metal anchors. The seamoss usually grow to the harvestable size within 4-6 weeks and are harvested at about 50 mm from the rope and usually individual plants are about 200 mm long. Production yields of GT grown on rafts is about 2 kg fresh weight per metre of the line in two months. At present, the total

combined area approximately under production has been estimated at one hectare, divided in 20 culture units. The whole sector is currently being operated by 5 full-time and 15 part-time farmers. The majority of the culture plots are presently concentrated in the Southeast and some locations in the Southwest.

Aquaculture technologies

The technologies developed and/or adapted in Saint Lucia for the culture of the Asian Freshwater prawn, tilapia and seamoss appear to be at the right level, bearing in mind the size (i.e. relative small scale) of the aquaculture projects being developed. Some applied research is still required to improve the technologies in use, for example: Gracilaria strain improvement, prawn feed development, prawn stocking and feeding rates. It is generally felt, however, that the culture technologies of the commercially attractive species must be maintained at an easily transferable/digestible level, and also at a level which is financially affordable to the small-scale farmers.

Aquaculture statistics

The production of Tilapia and freshwater prawns from the facilities in operation in 1991 amounted to 67 kg and 266 kg respectively. Both marketable size products, i.e. one pound per fish and 10-15 prawns per pound are sold and consumed locally. The ex-farm price is US\$ 1.11 and US\$ 5.61 for a pound of live weight fish and prawns, respectively. With regard to seamoss, no reliable annual production estimates are available, and for this reason the Department of Fisheries organized a national workshop in August 2002 to inform and assist farmers to start a common production monitoring system. Although the production data has not been officially registered, seamoss cultivation in Saint Lucia can be considered as commercial in terms of sales and production potential of the country. The ex-farm price is approximately US\$7.5 a pound of dried product.

III. POLICY MAKING, PLANNING AND MANAGEMENT

The Department of Fisheries (DOF) of the Ministry of Agriculture, Forestry and Fisheries is the public agency responsible for aquaculture policy-making and for the co-ordination of all planning and development efforts towards the sector. It is responsible for the acquisition of data and information, formulating policies, devising regulations and enforcing them as well as to provide technical assistance to existing farmers and interested investors. The DOF is headed by a Chief Fisheries Officer supported by a number of staff working in the various units. One of the above-mentioned staff, who has formal aquaculture training at the Diploma in Aquaculture Technology level, is presently responsible for aquaculture.

Aquaculture activities are included within a five-year management plan which was developed by the Ministry of Agriculture, Forestry and Fisheries. Aquaculture activities are further elaborated in an annual work programme.

IV. TECHNICAL CAPABILITIES

Education and training

No academic institutions exist in Saint Lucia where in-depth education and training in marine biology or related subjects such as aquaculture can be obtained. Formal education can, however, be obtained at the University of the West Indies: either at the Cave Hill Campus in

Barbados, Mona Campus in Jamaica and at the St. Augustine Campus in Trinidad and Tobago, although a specific programme in aquaculture is not available. Some practical training at the farmers' level can be obtained locally in prawn culture at the government Beausejour Prawn Facility in Vieux-Fort, and in Tilapia rearing at the small government fish Hatchery located in the northern part of the island (Union Aquaculture Facility). The Vieux-Fort facility, originally constructed with funds donated by the Chinese Government (Taiwan), as part of an agriculture co-operation programme, has a hatchery and office/house building and four earth ponds totalling a surface area of approximately 0.5 hectares. The hatchery has been designed for a monthly output of one million post-larvae. The head of the Aquaculture Unit oversees the hatchery. Other staff include a Fisheries Assistant with certificate level training and two support workers with on the job training. The Fisheries Assistant assists in the breeding of the post-larvae.

Research

Basic applied aquaculture research on tilapia and prawns can be carried out at the existing Government facilities. However, the unavailability of laboratory apparatus and supplies and limited manpower, reduces the possibility of research outputs focused on the solutions of specific feed development.

**NATIONAL REPORT
OF
SAINT VINCENT AND THE GRENADINES**

by

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I. GENERAL INFORMATION

Geography and Economy

<i>Area</i>	388 km ²
<i>Length of coastline</i>	150 km
<i>Shelf area</i>	7 800 km ²
<i>Terrain</i>	Mountainous volcanic island with rain forest cover on Saint Vincent, but drier and flatter in the Grenadines
<i>Climate</i>	Tropical
<i>Population</i>	110 022 (2001)
<i>Annual growth rate</i>	1.0% (2001)
<i>Language</i>	English (official)
<i>Work force</i>	58 000 (2001)
<i>Unemployment rate</i>	28% (1998)
<i>GDP</i>	US\$ 289 million (2001)
<i>GDP growth rate</i>	2.84% (2001)
<i>GDP per capita</i>	US\$ 2 655.00 (2001)
<i>Central Gov't budget</i>	Recurrent Revenue US\$ 96.2 Million (2000) Recurrent Expenditure US\$ 95.5 Million (2000)
<i>Currency unit</i>	Eastern Caribbean Dollar US\$ 1.00 = ECS 2.71 (May 2002)
<i>Agriculture</i>	10.5% of GDP (2001)
<i>Trade</i>	Exports US\$ 44.42 million (2001) Imports US\$ 185.77 million (2001)

Fisheries Data

Commodity balance (1999)

Fish for direct human consumption	Production	Imports	Exports	Total supply	Per caput supply
	'000 mt live weight				kg/yr
	1.71	0.19	0.10	0.80	12.50

Estimated employment (1999)

Primary sector	An estimated 2 500 part-time and full-time fishermen and occasional fishermen
Secondary sector	An estimated 2 000 working in marketing, fish vending, gutting/cleaning, boat building etc.

Gross value of fisheries output (at ex-vessel prices – 1999)

US\$ 2.58 million

Trade (1999)

Value of imports	US\$ 1 million
Value of exports	US\$ 0.74 million

II. STATUS OF AQUACULTURE

In 1983 small-scale experiments on aquaculture of *Oreochromis niloticus* (from Dominica) as well as *Macrobrachium* sp. and *Atya* sp. were carried out by the Fisheries Division of the Ministry of Agriculture at the Botanical Gardens. These experiments showed positive results and generated some interest among several sectors of the population, e.g. some primary schools and private individuals.

That same year a project from the Taiwan (Province of China) was established for the introduction of an agricultural development, with an aquaculture component which had the objectives of (i) promoting tilapia and freshwater prawn culture, and (ii) transferring the technology to local technicians. Unfortunately, this component of the project progressively faded because of lack of a local counterpart and was eventually phased out.

The site at Pembroke which was used (in the past) for the aquaculture demonstration site proved not to be appropriate, difference in water levels between the ponds and water supply was such that pumps had to be used to fill and empty the ponds. This increased the cost of production so that the aquaculture program was not economically viable. In addition, the soil composition at that site did not have a high water retention capability and if the site should be designated as an option in the future it is recommended that it would be necessary to line the ponds with clay soil to make them impermeable to water.

In March 2002, Mr. Lu Fong Gan, an Aquaculture Technician from the Republic of China (ROC/POC) visited Saint Vincent and the Grenadines (SVG), based on a request made to the Premier of the ROC by the Prime Minister of SVG during his visit to Saint Vincent in September 2001. The government of SVG requested the assistance of the government of the ROC/POC to evaluate the potential for the development of an aquaculture industry in the

state. During discussions held between the Technical Mission and the Fisheries Division, the scope of the evaluation was outlined. The outline included an assessment of the fishery industry potential based on on-shore culture, sea cage culture and seaweed culture.

A team comprises of representatives from the ROC/POC and the Fisheries Division, SVG visited several sites on main land Saint Vincent, and the Grenadines islands of Union Island, Bequia and Canouan. A pre-evaluation for the development of an aquaculture industry in SVG was prepared and submitted by Mr Lu Fong Gan. The following are the findings:

Fresh water aquaculture

The difficulty of onshore aquaculture in Saint Vincent:

- The absence of land appropriate for the setting up of ponds and the lack of a market for the product

Because the country is small, areas suitable to locate fresh water aquaculture are limited. In addition the size of the population is a deterrent to development of a freshwater food-fish industry that would achieve the necessary economies of scale to be profitable. However, if the focus of implementing a fresh water aquaculture activity is the provision of employment and the satisfaction of the local and tourist markets then the project can be pursued with reservation.

- The average difference between the river beds and banks is too great

During the evaluation process the Fisheries Division indicated several rivers where fresh water on shore aquaculture may have seemed viable, however with one exception, the difference in height between the river beds and their banks was so great that filling and draining problems would result. This problem could be resolved by either damming the river to raise the water level to that of the ponds or using a pump to fill and drain the ponds. Unfortunately, both resolutions would result in increasing the high cost of implementation.

Grant Sable is the only river with a potential for creating a pond through natural water flow but the available land area is only five acres. However, the project cannot be replicated anywhere else in the country as these optimum conditions do not exist elsewhere. Replication would be the key to economic viability.

- The soil texture is too sandy to retain water

Because the soil has a high component of sand it is loose and allows water to seep through. This problem can be solved by putting a layer of clay, or by lining the pond with plastic or by cementing the pond. This of course increases the investment cost.

The aforementioned difficulties can render attempts to develop on-shore aquaculture, even at a subsistence level, financially infeasible

Sea cage aquaculture

The leeward coast of main-island, Saint Vincent, is calm with some areas having depths of approximately 10 to 30m. These conditions would seem to be suitable for sea cage aquaculture. If the objective is to establish an industrial level sea cage culture in Saint Vincent, problems of natural disasters, inadequate feed supply and the cost of providing and

maintaining other infrastructure and facilities necessary for the successful operation of this industry must be solved. If the necessary facility construction and maintenance hardware have to be imported, then the investment in setting up and maintaining this type of industry would not be cost effective.

There is one feed producing factory in Saint Vincent but its production is limited to the production of feed for livestock. At present it does not have the capacity to produce aquatic feed, especially the technology for producing the floating food required by sea cage culture fish. In addition organizing a sea cage culture industry on the basis of a small economy of scale and intermittent consumers would make economic viability very difficult if not impossible.

III. CONCLUSIONS AND RECOMMENDATIONS

Saint Vincent is constrained by the limitation of its topography, as it does not have areas that can be developed into viable fishponds. It would therefore be difficult to institute an on shore aquaculture industry under these conditions.

The country is surrounded by sea especially the Leeward side where the water is suitable for sea cage culture, however, the country is prone to natural disasters, for example, hurricanes. Sources of constant feed supply need to be identified and knowledge of the market to determine which variety should be exploited needs to be documented. This would require that a more advanced evaluation be conducted.

Since there are many reefs surrounding Saint Vincent it would seem that there is a ready supply of decorative tropical fish for which there is also a ready market. It is possible that research into the reproduction of these species can be conducted to start an exotic fish breeding and exporting industry. This type of fish requires low investment, low maintenance and has a high end-value.

It may also be possible to expand an existing high value resource for example lobster by using sea cages to catch and fatten them for sale to an already existing market.

**NATIONAL REPORT
OF
THE REPUBLIC OF TRINIDAD AND TOBAGO**

by

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I. GENERAL INFORMATION

Geography and Economy

<i>Area</i>	5 128 km ²
<i>Length of coastline</i>	391 km
<i>Shelf Area</i>	80 000 km ² (EEZ)
<i>Terrain</i>	Plains and low mountains
<i>Climate</i>	Tropical
<i>Population</i>	1163 724 (July 2002 est.)
<i>Annual growth rate</i>	-0.52% (2002 est.)
<i>Language</i>	English
<i>Work force</i>	563 400 (1999) - Construction and utilities 12.4%, manufacturing, mining, quarrying 14%, agriculture 9.5%, services 64.1% (1997 est.)
<i>Unemployment rate</i>	10.7% (2001)
<i>GDP</i>	US\$ 10.6 billion (2001 est.)
<i>GDP growth rate</i>	3.5% (2001)
<i>GDP per capita</i>	US\$ 9 000 (2001)
<i>Inflation rate</i>	5.5% (2001)
<i>Central Government Budget</i>	US\$ 1.41 billion (2001 est.) revenues, US\$ 1.2 billion (2001 est.) current expenditures including capital expenditure of US\$ 930 million
<i>Currency unit</i>	Trinidad and Tobago Dollar (TTD) US\$ 1.00 = TTS 6.2314 (2001)
<i>Agriculture</i>	1.6% of GDP (2001). Products: cocoa, sugarcane, rice, citrus, coffee, poultry, fish, vegetables.
<i>Industry</i>	43.2% of GDP (2001). Types: petroleum, petrochemicals, tourism, processed food and beverages, cement, cotton textiles, printing and paper, assembly- type, chemicals and non-metallic minerals
<i>Trade</i>	Exports: US\$ 3.2 billion (f.o.b. 2000) - crude oil, petroleum products, ammonia, fertilisers, methanol, iron/steel, cocoa, coffee, citrus, flowers, fish.

<i>Imports</i>	US\$ 3 billion (I.o.b. 2000 est.) - industrial machinery, electrical machinery, transportation equipment, manufactured goods, food, live animals.
<i>Import-partners</i>	USA 39.8%, Venezuela 11.9%, EU 11%, CARICOM 4.8% (1999)
<i>Economic aid-recipient</i>	US\$ 24 million (1999 est.)
<i>Fiscal year</i>	1 October - September 30

Fisheries Data

Estimated employment

13 000 persons (1998)

Gross value of fisheries output (at ex-vessel prices - 2000)

US\$ 100 million

Trade

Value of imports	US\$ 3.94 million
Value of exports (2000)	US\$ 10 million - 4 000 mt

II. STATUS OF AQUACULTURE PRODUCTION

Species cultured and technologies

Inland aquaculture

Aquaculture had its genesis in Trinidad and Tobago in the 1950s when petroleum companies introduced the freshwater cichlid, tilapia (*Oreochromis mossambicus*) indigenous to the African continent, into their cooling-water dams to control breeding of mosquitoes. Subsequent to this, tilapia was perceived as an answer to the protein deficiency problem facing the colonies of the British Empire, since it could provide a cheap food source for low-income groups. The Bamboo Grove Fish Farm was established to research the culture of tilapia and produce fingerlings for farmers.

The initial focus of the Ministry at the time was to promote small-scale and subsistence farming using small family ponds in rural communities where marine fish was not readily available. Farmers were encouraged to use dams, irrigation channels and ponds to rear fish such as the red hybrid and silver variety and the indigenous catfish known as the cascadura (*Hoplosternum littorale*). Fish farming was an integrated activity with other types of farming such as animal husbandry, rice farming and other crop farming in order to maximize total food production within their holding.

Due to the poor marketability of the black tilapia, and following a recommendation of an Aquaculture Review Commission established by the Ministry of Food Production and Marine Exploitation (MFPMR) in 1986, the Institute of Marine Affairs (IMA) started an aquaculture unit with red hybrid and Nile tilapia (*Oreochromis niloticus*). In 1985, the IMA and Professor Kenny of University of the West Indies also introduced the Asian freshwater prawn, *Macrobrachium rosenbergii* to Trinidad. In 1988, La Vega Limited imported *Cherax*

quadricarinatus, and the Australian red claw crawfish. Among the indigenous species, the river conch, *Pomacea urceus*, was also successfully cultured by the IMA in the late 1980s.

In 1989, Caroni (1975) entered into commercial aquaculture. The pilot phase consisted of a multi-purpose hatchery and 9.5 hectares of earthen ponds. The company initially produced Malaysian prawns (1990-1995), and then focus shifted to the production of red hybrid tilapia. Cascadura was produced during the period 1992-1993. At the Government operated Bamboo Grove Fish Farm, a prawn hatchery was established in 1991 with technical assistance from Taiwan (Province of China). However, this project was never developed to realize its potential and it was discontinued when the Chinese left one year later. Also, in the mid-1980s, two farms were established: a tilapia farming venture on the eastern side of the Caroni swamp and a pilot project for shrimp at Brickfield. Neither ventures succeeded and were eventually closed down.

The Sugar Cane Feed is another demonstration facility of the MALMR, which was established to formulate feeds for the livestock industry utilizing sugarcane by-products. In 1988, an aquaculture project was established with the culture of the red and silver hybrid tilapia, and the cascadura, using 0.4 hectare pond area. The project was expanded by a further 0.5 hectare in 1990. The SFC advocated an integrated farming approach to agriculture and aquaculture. In 1988, a 3-hectare farm was established in Plum Miton to culture cascadura on a semi-intensive basis. In parallel a commercial fish hatchery was established in Gran Couva to provide fingerlings for the fish farm. These projects initially went well but disease and larceny problems developed which impacted negatively on operations. The hatchery subsequently entered into ornamental fish production and eventually ceased operations due to an irregular supply of water.

In the early 1990s, the red hybrid was the major freshwater fish species cultured throughout the country on a small-scale. Other freshwater species being cultured to a small extent were the Nile and black tilapias and the armoured catfish, *Hoplosternum littorale*. The IMA has conducted a number of hatching trials of the freshwater prawn and has supplied post-larvae to several small-scale fish farmers. After the poor success experienced with the culture of the red hybrids by most aqua farmers, the Wallerfield Fish Hatchery attempted to re-introduce the Nile tilapia, *Oreochromis niloticus*, as a new species in 1997, with the hope that claims of its growth potential would stimulate interest in purchasing fingerlings. The hatchery was capable of producing 1 million *O. niloticus* fingerlings yearly. But in the absence of external farms and available land for grow out; production was curtailed until the industry can absorb this output.

The ornamental fish industry has a longer history and there are about six large-scale producers who also export. There are approximately thirty-nine small to medium-size breeders who concentrate on the rearing of several exotics and indigenous species. The major species produced are: Angels, Barbs, Goldfish, Danios, Swordtail hellaries, Mollics, Platies, African cichlids, Bettas, Kois, Tetras, Rainbow fish, Gouramies, Oscars, White clouds, Tetras, Guppies and Pui-Pui. The latter three species are indigenous to Trinidad and are usually harvested from rivers in rural areas. Stocking studies are currently be undertaken by the IMA to restore wild stocks of teta, which is currently overexploited.

Coastal aquaculture

Presently no commercial coastal aquaculture operations exist in Trinidad and Tobago. Attempts have been made to culture various species of penaeid shrimps (*Penaens monodon*

and *Penaeus vannamei*), however, to date none of the former farms and pilot projects are in operation. Presently, there is little or no interest in coastal aquaculture activities. Until the early 1990's, there was a strong market demand for the mangrove oyster (*Crassostrea rhizophorae*). The above-mentioned oyster was once very abundant in the Caroni and Nariva Swamps. However, due to over-harvesting, the numbers are much reduced and now collected mainly from the Claxton Bay region. Additionally, the vending of oyster cocktails, which was a major source of oyster sales, was significantly affected when a ban was imposed on vending in 1994 due to sanitary concerns. This enterprise was never able to recover even though in 1996, the Oyster Vendors Association attempted to save the industry by proposing a culture project in the Caroni swamp. The project was to be funded by a Florida based agency but for reasons, which are unclear, the project was never started. In 1995, mariculture trials were conducted using seamoss, *Gracilaria* sp. and the carangids, *Trachinotus* sp.

Aquaculture technologies

Several reasons have been cited for the failure of aquaculture in Trinidad and Tobago. Among those reasons are the following: the transfer of inappropriate production technologies to farmers, the subsistence technology that is used in small backyard production units, and the use of extensive culture systems that are not commercially viable and or will not ensure the sustainability of an industry. Also, failure in the use of sex-reversal technology to produce all male fingerlings for stocking of production ponds has made it difficult for farmers to manage production units ultimately resulting in poor yields at harvest time. The recent thrust of the Fisheries Division has been sensitising the national community about aquaculture, and encouraging commercial scale production units of ½-acre to 1-acre minimum size and minimum production capacity of 5 acres or 2 hectares. Incentives are being given to farmers, effective 1999, which meet these minimum criteria.

Aquaculture statistics

The total number of registered fish farmers in December 1991 was 1 020 while the total area of ponds (ranging in size from 0.05 to 5.0 hectares) amounted to approximately 120 hectares compared to the 23 hectares in production in 1985. Most of the 1028 farmers practised small extensive backyard fish farming and they were located in the countries of Caroni, St Patrick and Victoria. No mechanism had been put in place by the Fisheries Division to collect data on these Freshwater Fisheries. However, in 1999, a telephone survey was conducted to identify the number of practising food fish farmers in the nation.

Of the fifty-three existing farmers identified in that survey, forty-three were determined to be cascadura subsistence and small-scale farmers who depended largely on capture fisheries for brood stock and even market supply. Four of these projects practised polyculture with Tilapia. The Sugarcane Feed Centre, the Bamboo Grove Fish Farm and Caroni (1975) Ltd. were also counted among the fifty-three. However, Caroni Aquaculture Division closed down all production operations by late 1998 and the Bamboo Grove Fish Farm was divested in 1999. The lessee has only recently (2002) initiated small-scale production at this facility.

Generally, it was discovered that Tilapia production was not being practised on a wide scale. The Fisheries Division established one, 0.2 hectare, pond in each of two rural communities as demonstration projects. This initiative attempted to encourage both a co-operative approach to production, as well as to seed other production units. In each case, only male *O. niloticus* fingerlings were stocked. Two more community-based projects were established between 2000-2001 providing additional five, 0.2 hectare, production ponds and a capacity of 23 tonnes of fish yearly. These demonstration projects helped to provide valuable hands-on

training to community members but once the Division withdrew financial support for a project no further investment in the project was found.

No reliable production statistics are available to date, however, the Aquaculture Unit of the Fisheries Division, reported that in 1991 approximately 2.5 metric tonnes of fresh fish were sold, mainly red-hybrid tilapia. The combined production figure for the cultured freshwater fish species is likely to be an underestimate as very little of the total production reaches the local markets. Tilapia, as well as the highly regarded cascadura, usually serves the farmer and his immediate family. The former species are rarely sold, while the cascadura, when sold, is taken to the produce market and retailed by the farmer to his/her agent at TTS 44/kg. The SFC produces about 2 tonnes of fish yearly but since research and not production is the emphasis this quantity is not guaranteed.

The Central Statistical Office only commenced the collection of production data for the cultured food fish industry in 1998, and the information is limited to that supplied by Caroni (1975) Ltd. Over the period 1990 to 1996, Caroni (1975) Ltd was the largest producer of cultured food fish in the country and accounted for an estimated 98% of the Malaysian prawns produced, 80% of the cascadura produced and 70% of the tilapia produced. It is reported that in 1991, Caroni (1975) Ltd produced 5.2 metric tonnes from 5.5 hectares. Table II, below, provides data for the period 1990 to 1996. By 1999, no projects were established which cultured freshwater prawns.

YEAR	SPECIES (Quantity in Kg & Value in US\$)					
	Tilapia	Value	Cascadura	Value	Prawn	Value
1990	1250	1,600	2000	12,000	-	-
1991	1250	1,600	1250	8,100	5200	20,000
1992	2500	1,600	4000	16,900	2000	4,000
1993	2800	4,000	2500	9,600	2500	8,800
1994	16000	23,460	1250	4,100	2500	9,600
1995	16000	2,300	1200	4,000	3000	12,900
1996	18000	29,000	1200	4,000	500	1,600

In 1999, Wallerfield Fish Hatchery produced approximately 200,000 fingerlings and 10 tonnes of fish. In 2000 approximately 50 000 fingerlings and 15 tonnes of fish were produced. In 2001 and 2002 there was no production. The Nariva Aquafarms is a twenty-acre farm, which initiated its production operation in 1999. From 1999 to 2001, half tonne of cascadura was produced each year. In 2000, half tonne of red hybrid tilapia was produced in earthen ponds. In 2001, two tonnes of fish were produced. In 2001, approximately 3.6 tonnes of fish were harvested from two community projects. In 2001, the two projects yielded almost 2.4 tonnes fish.

In the ornamental fish trade, expanding export markets have been identified in North America and Europe. In 1999, 10 ornamental fish exporters sold a total of 1 375 000 fish generating an income of approximately US\$ 130 000. These figures are believed to be under-estimated. It must be noted, however, that not all of these fishes were produced locally by aquaculture, and that some are captured from local rivers while others are imported from South America using Trinidad as a transhipment point.

III. POLICY MAKING, PLANNING AND MANAGEMENT

The Fisheries Division (FD) of the Ministry of Agriculture, Land and Marine Resources (MALMR) is the official agency responsible for the management and development of the fishery sector, including aquaculture. The major role of Fisheries Division is the development, organisation and regulatory support to the industry through policymaking and strategy implementation. Extension, training and information services are also provided via the assistance of the Fisheries Officer and the scientific assistant.

The Government of Trinidad and Tobago, in its macro-economic policy framework (MTPF 2001-2003) enunciated its overarching strategy for Aquaculture as *'A Strategy for generating additional employment in the sector include-increasing access of farmers, fisher folk and aquaculturalists to agricultural credit'*. The MTPF also states that *'In respect of marine fisheries and aquaculture, Government, as part of its efforts to promote sustainable management of natural resources, will seek to provide institutional and infrastructural support to fisher folk and aquaculturalists; and establish links with national and international agencies for the necessary financial and technical support'*. The role of the State is also articulated in the Sector Policy for the Ministry of Agriculture, Land and Marine Resources (2001-2005) as follows: *"The State will facilitate private sector activity by producing public goods and services in support of private sector activity and improved livelihood for citizens. The MALMR considers the aspect of enforcement of regulations and provision of certification, including but not limited to public health and food safety as essential. The Ministry will accommodate the needs of stakeholders for speedy and transparent decisions and actions in the conduct of its regulatory and certification responsibilities"*. The facilitative role of the State includes its functions with respect to development and enforcement of regulations and standards for quality assurance, also intervene in markets, for limited periods, to assure supply of some 'strategic' goods not provided by the private sector'.

In 1997, a task force consisting of six representatives from the UWI, IMA, SFC and Fisheries Division was appointed to formulate an aquaculture policy for the benefit of the emerging industry. Dr Indar Ramnarine headed the task force and a draft aquaculture policy document was produced. This document has undergone two to three revisions, but it is still to be finalised before being sent forward for cabinet consideration.

IV. TECHNICAL CAPABILITIES

Education and training

The only institution in Trinidad and Tobago, which carries out formal education at the graduate level in the field of biology and related subjects, is the St. Augustine Campus of the University of the West Indies (UWI). The Department of Zoology has no specific programme in aquaculture, however, courses on fishery/aquaculture/estuarine sciences are available as part of the zoology degree. The UWI, however, expressed interest on a possible tough M.Sc. course in fisheries and aquaculture, provided that it is fully conducted in only one of its campuses. It is generally felt that there would be sufficient interest for such a course, which could be conducted on alternate years.

Hands-on training can be received at the Institute of Marine Affairs and at the small Aquaculture Unit of the Sugarcane Feeds Centre. The Fisheries Division has for the last two

years (2000-2002) been offering an intensive six-day training course in Food Fish Farming. In the last fiscal period, the Introduction to Ornamentals and Integrated Farming was introduced for the benefit of the emerging industry.

Research

The Institute of Marine Affairs (IMA) is an autonomous government institute established with the following objectives to:

- promote the better understanding of all aspects of the marine environment;
- disseminate in the Caribbean knowledge of the various disciplines relevant to marine affairs; and
- increase the capabilities of the Government in the formulation of policies in marine affairs. Aquaculture research is one of the programmes of the Institute.

The Pilot Aquaculture Project was initiated at the IMA in 1985 and was intended to conduct field and laboratory trials with a view to identifying potentially suitable culture species for Trinidad and Tobago. In former years, production and culture trials were conducted on the cascadura (*H. littorale*), the red hybrid tilapia and the freshwater giant prawn (*M. rosenbergii*). Some work was also being carried out with the Nile tilapia (*O. niloticus*), the freshwater black conch (*Pomacea urcea*) and seamoss (*Gracilaria* spp.). IMA's applied research concentrated on the following topics:

- polyculture of freshwater prawns and cascadura
- production of red hybrid tilapia and cascadura fry and fingerling
- production and cage culture of the grey snapper (*Lutjanus griseus*) and pompano (*Trachinotus* sp.), and
- seamoss raft culture.

The output of this research is the documentation of several manuals by Paul Gabbadon and Gregory DeSouza for the benefit of potential and existing aqua farmers.

The Institute is equipped with office space, a library, an analytical laboratory for water analysis, a wet laboratory, hatchery, nursery and nine small earth ponds (total surface area approximately 0.5 hectares). Presently, the research of the Aquaculture Division is directed to the ornamental industry with regard to fish pathology, culture techniques and re-introduction of wild stocks into their natural environment. There is greater emphasis on environmental studies and some of the professional staff have moved into providing technical consultancy on environmental issues.

The Sugarcane Feeds Centre (SFC) is conducting culture and production trials on the river conch for very little is known on the feeding requirements and the reproductive behaviour of this local delicacy.

The Life Sciences Department of the University of the West Indies, St Augustine Campus, has been carrying out some basic studies on freshwater and brackish water species of commercial interest. The campus is not equipped with research aquaculture facilities, however the Bamboo Grove Fish Farm (BGFF) was divested to Dr I. Ramnarine who is a senior lecturer at the Department of Life Sciences, UWI. Dr I. Ramnarine together with the university students are therefore able to continue developing and implementing applied fishery research projects utilizing the facilities at BGFF.

Technical assistance and extension

The Sugar Feed Centre and Fisheries Division continue to provide technical assistance and extension services to farmers. However, this service is not in demand as much as the need for training. The above centres usually provide, free of charge, the following assistance:

- assessment of the land and water resources of an applicant
- preparation of feasibility studies
- advice on the biological aspects of the species being considered and/or cultured,
- advice on pond design and construction, and (v) advice on farm management practices.

The objectives of the Aquaculture Extension Programme are:

- to demonstrate certain fish culture practices so that the farmers can be acquainted with the scientific method of fish farming;
- to act as liaison between the research units and the farmers, so as to ensure that new and improved techniques are transferred to the farmers in a language readily understood; and
- to support farmers in all aspects of their aquaculture project.

The Sugarcane Feeds Centre, with its small hatchery and few culture ponds, has adopted an open-door policy where all interested parties can observe and receive advice on the management of small-scale cascadura and tilapia operations. The Institute of Marine Affairs also provides technical assistance and extension services to fish farmers in the form of hands-on technical workshops, seminars and technical manuals.

In 2001, National Flour Mills (NFM) hosted a seminar on '*Tilapia Feeds and Nutrition*' conducted by the American Soybean Association. The follow-up to this was another seminar in May 2002 on '*Achieving Optimum Efficiency in Aquaculture Production*'. The NFM entered the aquaculture industry in 2000 as a commercial producer of starter and grow-out extruded fish feeds. This business initiative was undertaken in order to supply the Jamaican market where demand was not being met by supply. This organisation has decided to promote aquaculture production in Trinidad and Tobago and consequently, it is expected that seminars of this nature will continue in the future.

V. POTENTIAL FOR AQUACULTURE DEVELOPMENT

Physical potential

Trinidad and Tobago are the southern-most islands of the Lesser Antilles chain in the Caribbean. Trinidad, the largest island of the chain, is separated from Venezuela by the 11 kilometre-wide strait of the Gulf of Paria. Three relatively low mountain ranges cross Trinidad from east to west. Their highest elevation reaches 940 metres in the heavily forested Northern Range. Between the northern and central ranges the land is flat and well watered; between the central and southern ranges it is rolling, and the water supply often falls short in the dry season. Tropical forest covers half of the island. Swamps are found along part of the east and west coasts. The island's low latitude places it outside the usually path of hurricanes. The island of Tobago lies 30 kilometres northeast of Trinidad and is characterized by long

stretches of sandy beaches and a ridge of volcanic origin which lies along the centre of the island.

The suitability of Trinidad and Tobago for aquaculture was discussed in the 1998 FAO document *'A strategic assessment of the potential for freshwater fish farming in the Caribbean island states'*. Six major criteria were used for the evaluation exercise:

- Market size and proximity: based on population density at urban centres and estimated travel time along roads to reach urban markets;
- Water loss from ponds by evaporation and seepage: annual water loss is estimated from precipitation over the pond and its embankments, evaporation are from the pond surface and seepage is assumed to be a constant;
- Soil and terrain suitability for ponds;
- Potential for agriculture by-products: inputs for fish farming as fertilizers or feeds on the basis of crop potential;
- Farm gate sales: depends on population density local to the farm site but does not take into account purchasing power or disposable income; and
- Farming system criteria combined: combining the criteria weighted by their relative importance.

Trinidad and Tobago scored high on the basis of the importance placed on annual water loss; soil conditions were also determined to be favourable. Generally, good quality water in adequate supply is found on the eastern side of Trinidad in the Oropouche, Nariva and Ortoire basin and along the north coast between Chupara and Grand Riviere. With regard to freshwater swampland, extensive unpolluted areas are available at Nariva in the east and Los Blarquizales in the southwest.

Most of the more extensive areas of brackish water swamp are under pollution risk, but the southern half of the Caroni Swamp and the Fullarton Swamp still have reasonably good quality water. Sheltered marine areas suitable for mariculture are available in the Gulf of Paria but pollution and other commercial activities is a serious problem. Other bays on the North coast, such as Teteron Bay, Chacachacare Bay, Maracas Bay, Las Cuevas Bay, Cyril Bay, Man-of-War Bay and Bloody Bay can be effectively used. If mariculture is to be done in ponds or tanks next to the marine environment, then there are other potential sites on the South and East Coasts. In Tobago, good quality freshwater is available in limited quantities. Excellent conditions are available for mariculture in Buccoo and Bon Accord and in the deeper West Coast bays.

Species

The aquaculture industry as a whole is still at an early stage of development and the potential for expansion exists. However, factors such as market demand, availability of technology and resources must all be taken into account in order to determine whether the culture of any particular species is economically attractive and justifiable. A brief survey of local species indicated that Trinidad and Tobago have many organisms with value for culturing.

These organisms as well as a number of non-endemic species would fill the various needs in the country, i.e. as basic or luxury food items, recreational fishing and aquarium export trade. Some species could be successfully and profitably cultured within one or two growing seasons (e.g. cascadura, mullet and oysters), while other require more research before their

future economic returns can be assessed (e.g. queen conch, crabs, marine plants, marine shrimps).

Beside tilapia, cascadura and the giant freshwater prawn, the potential exists for the following types of culture.

- Culture of brackish water shrimp in coastal ponds;
- Culture of indigenous ornamental fish species (e.g. *Corydoras aeneus*, *Hypostomus robinii*);
- Mariculture of tilapia and other indigenous marine species in cages;
- Culture of indigenous freshwater species in ponds; a
- Culture of bivalves in coastal areas (*C. rhizophorae*, *Perna* sp.).

Finance

The Aquaculture Task Force reported that one of the major impediments to the development of the industry is the stringent requirements in accessing available capital. The Task Force was of the view that the Agricultural Development Bank (ADB) should provide the best available loan conditions for aquaculture projects. Under the Agricultural Incentive Programme, there is an integrated package of fiscal incentives to stimulate greater interest for investors in the industry. These include duty-free concessions on aquaculture equipment and some supplies, corporate tax reductions to fish processors, and rebates for pond construction, rehabilitation of ponds, construction of wells, pumps, vehicles, and minor equipment. A waiver of charges on water used is being discussed. No taxes are paid on agricultural holdings of with less than 100 acres in production.

VI. FISH HANDLING, PROCESSING AND MARKETING

Aquaculture production is mainly subsistence in nature with a very small portion of the catch being marketed-fresh to local consumers. Presently none of the existing fish processing plants handle aquaculture products, mainly due to the small annual outputs. However, should production from aquaculture substantially increase, there are adequate fish processing plants to absorb the raw material for processing into value-added products.

Marketing information and facilities have been identified as major constraints to the development of the aquaculture industry in Trinidad and Tobago. Presently, there is little or no current market information available to the industry. Production decisions are made in the absence of adequate market information and as such, producers are probably not able to maximize their potential and exploit market demands. The Aquaculture Task Force recommended that the National Agricultural Marketing Development Co-operation, with the assistance of the Export Development Corporation (folded in 1993) and various trade missions, develop a comprehensive marketing information gathering system, which would provide important information on a regular basis to the industry.

With regard to marketing facilities it has been recognised that adequate storage facilities are not available as well as the need for an efficient and low cost supply of packaging materials. There is also need for greater co-ordination among agencies involved in the inspection of fisheries and aquaculture exports. The strengthening of the organisation and support services to the industry is recognised as a priority to enhance the development of the sector.

VII. CONCLUSIONS AND FUTURE DEVELOPMENTS

There is need for a proper marketing study to be conducted, which would identify the potential markets for Trinidad and Tobago fish and fishery freshwater products including market characteristics, product requirements, competitive producers, market prices and so on. The only marketing study to date was conducted by IMA into consumer preferences for tilapia on the basis of freshness, features and colour, in the early 1990s. There exists a cultural bias in the country for fresh marine fish and consumers are generally unwilling to consider alternatives of like tastes unless they are prepared, processed and packed for convenience. Aquaculture products are therefore niche products at present; acceptance being mainly in the rural communities. There is need to organise public awareness and education programmes aimed at promoting fresh water fish consumption.

Although aquaculture activities have been in existence for over fifty years in Trinidad and Tobago, the fishery has yet to develop commercially. It is believed that this can be achieved via the establishment of an Aquaculture Management Authority (AMU), to oversee the development and implementation of a National Aquaculture programme. This institution would facilitate cooperation and collaboration among all stakeholders, including government institutions, non-government organizations NGOs, private investors and fish farmers. A determination of the domestic protein requirements measured against local production and quantities lost to the local market through exports can be used as a basis for setting production targets and a production plan must be formulated. The AMU would also be responsible for marketing fish and fishery products as well as training and monitoring the progress of projects.

There are about three investors who have proposed lucrative commercial-scale inland fishery projects to the Government of 40.5 hectares (100 acres) upward but implementation is hindered because of the long delays in being provided with a lease agreement. This is in part due to political issues not to mention that land is at a premium and the competition with other economic interests is intense. Lands have not been identified in the MALMR for Aquaculture in like manner to lands reserved for agriculture. To facilitate this process there is need for a detailed technical and economic feasibility study to investigate opportunities and provide specific options for profitable investment.

In summary, the Government of Trinidad and Tobago and the private sector seem seriously committed to the promotion and development of the aquaculture industry. However, the implementation of policy and other measures are not being pursued with the necessary vigour and determination to continue to motivate the private sector. As a result, the private investors are undertaking bold initiatives to encourage market interest and to lobby the Government. One such initiative is the establishment of the Aquaculture Society of Trinidad and Tobago, which replaces the Fisheries Society, which became dormant in 1994.

Other issues to be addressed to facilitate this fragile industry include:

- High production costs as a result of costly feeds and costly seed stock;
- Insufficient institutional capacity and human resource capability;
- Inadequacy and lack of proper access to information and research;
- High cost of water.

PART III

REPORTS FROM THE RESOURCE PERSONS

**MARKETING OPPORTUNITIES FOR AQUACULTURE PRODUCTS
IN THE
LESSER ANTILLES**

by

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INTRODUCTION

Sustainable development of aquaculture is only possible when there is a market for the commodities produced. A precondition for aquaculture to take off is that consumers, locally or in export markets, should be interested in its products. In the next sections the trade of fishery products by the SIDS of the Lesser Antilles and Bahamas, the markets for aquaculture products in the USA and EU, current trends and prospects for fish consumption and issues of importance to commercially oriented aquaculturists will be discussed subsequently.

Trade in fisheries products

The trade in fisheries products by the SIDS of the Lesser Antilles and the Bahamas shows large variation between the various countries. Export and import data of fisheries products in the year 2000 are detailed in Table 1 below.

Table 1: Exports and imports of fishery products by the SIDS of the Lesser Antilles and Bahamas in the year 2000 (Source: FAO FishStat Plus).

Country	Exports in Metric Tonnes (2000)	Imports in Metric Tonnes (2000)
Trinidad & Tobago	4 361	4 028
St Vincent & Grenadines	251	421
Bahamas	3 440	1 634
Grenada	542	438
St Lucia	7	1 249
St Kitts & Nevis	73	1 376
Barbados	297	3 798
Dominica	0	666
Antigua & Barbuda	644	470
Total	9 615	14 080

Taking in consideration the balance of trade in fishery products, only three of the nine above listed countries showed a positive sign, being Bahamas, Trinidad and Tobago, and Grenada. The other countries spent more on fisheries products imports than they earned with exports in 2000 (Figure 1). The positive balance of the Bahamas is largely a result of the high value of the spiny lobster exports. When specifying the imported fishery products by product class,

tunas (prepared or preserved), fish various (dried, salted or in brine) and sardines (prepared or preserved) appear to be the main imports. The lack of detail in the data available makes it impossible to distinguish between the sources of origin of the fisheries products (capture fisheries or aquaculture). It is safe to say that most of the currently being imported products originate from capture fisheries, however, some of these products could be derived from aquaculture as well. Considering the current aquaculture production of the SIDS of the Lesser Antilles is largely limited to tilapia and shrimp it might be useful to look at the import trends of similar products. Figure 2 details the imports of some of the fisheries products by class in 1990 and 2000; products that might be partly derived from aquaculture. The figure shows that imports of frozen shrimp more than doubled, and those of frozen fish fillets increased from insignificant to over 1600 mt and fresh fish fillets to over 500 mt over a 10 year period.

As the population of the SIDS of the Lesser Antilles is relatively small, a large part of the demand for fisheries (incl. aquaculture) products should come from tourism if aquaculture is to be economically viable. Aquaculturists should take advantages of the needs for fresh, safe and high quality fish by the tourism industry. Steady supplies are demanded by caterers and restaurants/hotels, which can only be guaranteed by the aquaculture sector or imports.

Exports of fisheries products from the SIDS of the Lesser Antilles and Bahamas are largely going to the USA. Main export products are frozen lobster (Bahamas), fresh yellow fin tuna (Trinidad and Tobago, Grenada, Barbados) and frozen albacore tuna (St. Vincent and the Grenadines).

Trade policies that affect fisheries products trade between the SIDS of the Lesser Antilles and USA and Canada are among others: The Caribbean Basin Initiative (CBI), which is a broad programme to promote economic development through private sector initiative in Central America and the Caribbean. It especially promotes investment in non-traditional sectors such as aquaculture. Under the Caribbean Basin Economic Recovery Act duty free entry of fresh and frozen seafood is being provided for. However, canned tuna is excluded from this duty free entry status. Under the CARIBCAN fisheries products from the SIDS of the Lesser Antilles have duty free access to the Canadian market, provided that they originate from the Islands.

European Union trade policies that impact the trade of fishery products between the SIDS of the Lesser Antilles and the EU are largely based on the Lomé Agreement (1975), the Cotonou Agreement (2000) and various EU directives. Since the early 1990's the EU has emphasised that fishery and aquaculture products entering the European market should be of high quality. This was written down in various directives. An important directive for fish farmers from the SIDS of the Lesser Antilles is Directive 91/493/EEC that lays down the health conditions for the production and the placing on the market of fishery products. In short, Directive 91/493/EEC stipulates that all fishery and aquaculture products (fresh, as well as chilled, frozen, canned, smoked, dried or salted) entering the EU market must come from a an establishment where fishery and/or aquaculture products are prepared, processed, chilled, frozen, packaged or stored which is approved by the competent national authorities. For the implementation of these EU Directives the EC is developing harmonised import conditions for the third countries exporting fishery and aquaculture products to the EU. The specific conditions for imports of specific products and product forms are being documented, which is a long process. Therefore, a transition period has been defined, during which so called "third" countries are allowed to export fishery and aquaculture products to the EU. Not-harmonized countries are not allowed to export fishery and aquaculture products to the EU. Provisionally

harmonized countries among the SIDS of the Lesser Antilles and Bahamas are at the time of the workshop: Antigua and Barbuda, Bahamas and Grenada. This means that the other countries are not harmonized and thus not allowed to export fishery products to the EU. If harmonized the General system of Preferences (GSP) becomes important as it allows for duty-free access without any quantitative restrictions to products originating in the Least Developed Countries (LDCs). This includes fisheries and aquaculture products as well.



Figure 1: Trade balance of fishery products of selected countries in million US\$ in 2000.

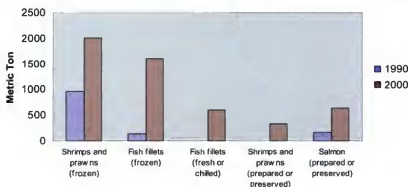


Figure 2: Growth in imports of certain fishery product classes in the SIDS of the Lesser Antilles and Bahamas between 1990 and 2000.

Consumption

The consumption of fishery products varies largely between and within countries. Figure 3 presents the fish consumption in a number of EU countries and the USA, relevant as (potential) export markets for fisheries/aquaculture products from the region. Portugal has the

largest consumption of fish per capita in the EU, 61 kg/year, followed by Spain with 41 kg, Finland 34 kg and France with 31 kg/capita/year. Austrians, Germans and Dutch only consume between 11 and 16 kg per person per year. Average consumption in the USA is around 21 kg/capita/year.

Although no fishery products consumption data were available from the SIDS of the Lesser Antilles, supply data were. In the SIDS of the Lesser Antilles the per capita supply of fishery products is generally higher than 15 kg (except in Trinidad and Tobago) (Figure 4). This does not mean that there is sufficient fish available, but is just a calculation of the production + imports – exports of fishery products divided by the population size. Consumption by tourists is not considered in this figure. When including the consumption by tourists the total supply per capita would be much smaller. Since 1990 the per caput fish supply increased in St. Lucia, St. Kitts and Nevis, Barbados, Dominica, Trinidad and Tobago and Antigua and Barbuda. However it decreased in Grenada and the Bahamas over the same period. Recent fish consumption forecasting studies expect an increasing trend for the coming 50 years. However, up until 2010 the expected increase in consumption per year per caput is just over 1 kg in Latin America. For instance in Asia, Europe and North America the increase will be around 2 kg over the same period. Relating the fish consumption trends to the increase in regional global population the differences are larger. Africa, Asia and Latin America will need a much larger supply of fish than they have now available. As production from capture fisheries is not growing sufficiently most of the increase in supply will have to come from aquaculture.

The trend in fish consumption in the USA and EU is towards an increase in fresh and value added products (e.g. sashimi, ready to eat fish soups, paella and fish salads), while a slight decrease can be seen in the consumption of whole frozen fish and canned products. As far as the market for shrimp products concerns, the following trends are visible:

- Variation in products increased. Individual Quick Frozen Techniques (IQF) has contributed to this trend. Also the availability of especially battered products and the use of shrimp in ready to cook products (soups, paella) are increasing.
- Demand increased again after 2001 (now 15% higher in US).
- Wholesale prices in US are 19% down compared to last year.
- EU imports increased as well (especially in France).
- Competition is high from Asia (Thailand, Vietnam) and Africa (Madagascar, Mozambique) in EU market.
- Chloramphenicols remain a problem.

The tilapia market is characterized by the following:

- Production also in Jamaica and Costa Rica.
- Fresh fillets reach the EU market within 24 hours.
- EU imports of tilapia are mainly coming from Zimbabwe, Israel and Jamaica.
- In EU competition from Nile/Lake Victoria Perch and Tilapia.
- Demand increased rapidly during the last decade in US.
- In EU main consumption is by ethnic groups in UK, Germany and France.
- Fillets available in supermarkets at low prices.
- Consumer acceptance is rising (low calories).
- Consumers in the EU prefer bigger sizes than the USA and fresh over frozen.

Regarding the consumption of aquaculture and fisheries commodities it should be noted that aquaculture products have a considerable advantage over products derived from capture fisheries. Main advantages of aquaculture products are: 1) Homogeneous size of products, 2) Homogeneous meat/flesh colour, 3) Year-round availability, 4) Less odour (preferred by some consumers), 5) Taste can be adapted to local preferences, 6) Traceability and control, 7) Less damaged products as result from handling/bringing on board, and 8) Prices are generally low and predictable.

Following the above issues on trade, marketing and consumption commercially oriented aquaculturists should take into consideration some strategically important issues:

1. Produce a specie that has demand locally or in the US or EU, in other words a specie that is commonly known.
2. Keep records of all inputs and outputs of the production process.
3. Collect trade and price data (domestic & export) from internet & other sources.
4. Prepare a business plan including a clear marketing plan, financial analysis and if necessary a lending analysis.
5. Contact possible trade partners (CARICOM, US and EU)
6. Keep up-to-date on prices, markets and regulations.
7. Use written contractual agreements.

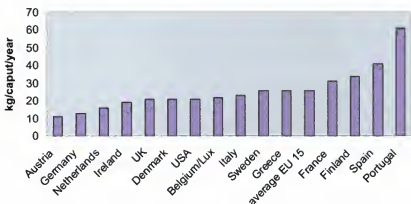


Figure 3: Average fish consumption (kg/caput/year) in EU and USA (period 1994-1998).

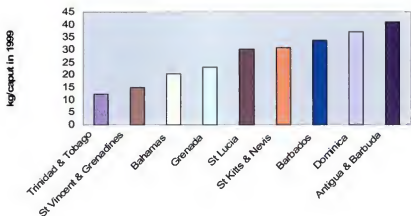


Figure 4: Supply of fish and fishery products in the SIDS of the Lesser Antilles and Bahamas in kg/caput live weight equivalent.

**AQUACULTURE DEVELOPMENT OF RED DRUM
(*SCIAENOPS OCELLATUS*) IN MARTINIQUE AND THE
FRENCH WEST INDIES**

by

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SUMMARY

The aquaculture of red drum (*Sciaenops ocellatus*) has been the subject of research and development work in Martinique since 1985. It was during the initial eight-year period that research findings showed the suitability of the species for domestication and mariculture.

However, whilst biological and technical knowledge is a compulsory prerequisite, it is not the only requirement for development. Operations throughout the production chain need to be synchronised, right through to product selling and company profitability. This explains the lengthy development process.

Since 2000, research reorganisation at IFREMER, the separation of larval rearing from growing-out, and the political and financial support of Martinique Region, have given a fresh impetus to our work, and development is now really taking off.

However, Martinique should not be the only island to benefit from this example; other Caribbean countries must also be given the opportunity to put the small-scale aquaculture model into practice.

INTRODUCTION

IFREMER has had a mariculture research department since its establishment in 1968. Interest quickly focused on the initial species considered for development at that time (fish, crustaceans and molluscs) and a small number was selected for farming.

The Robert station was established in the early seventies and began work on filter-feeding bivalves (oyster culture trials), giant freshwater prawns (*Macrobrachium rosenbergii*) and some fish species. The European sea bass (*Dicentrarchus labrax*) was the key species, due to the fact that its growth in the tropics is greatly accelerated by water temperature.

However, this stock was wiped out by a virus (*Nodavirus*), which led to trials on other species from 1985.

In 1985, the Association for Aquaculture Development in Martinique (ADAM) introduced red drum (*Sciaenops ocellatus*) from the American coasts (Gulf of Mexico and Southern Atlantic). In the early seventies a restocking programme to support natural stocks was successfully developed. Between 1990 and 1995, intensive aquaculture techniques were adapted with considerable help from the local IFREMER laboratory.

The potential for mariculture in Martinique is very good. There are many suitable sites, some in the Caribbean Sea, protected from the prevailing winds, others on the Atlantic coast, the southern half of which is protected from the swell by an off-shore barrier reef, demarcating a wide area suitable for development (Figure 1).

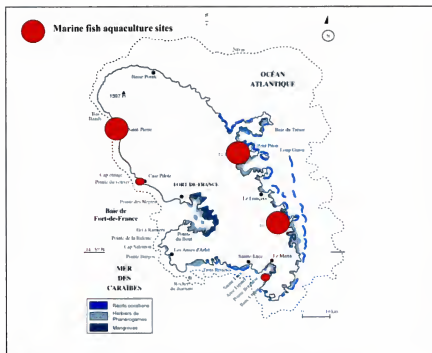


Figure 1. Suitable coastal areas for mariculture development in Martinique.

In 1995, a development framework was set up, based on a regional hatchery providing juveniles to aquaculture farms. This programme was not put into operation for several reasons:

- under-estimation of the technical skills required for hatchery development;
- inadequate training for aquaculturists; and
- inadequate management skills.

This meant that fingerling output was unpredictable, thereby hindering the development of the species.

In late 2000, the programme was reviewed in terms of the use of aquaculture potential, the role of the various players and how to make the most of the available opportunities. The effect of this was that, in 2002, fish were beginning to be marketed, there were requests to set up new hatcheries and professional skills were being organised.

Before the Introduction of Red Drum

The first species to be used for mariculture was the European sea bass (*D. labrax*), one of the few species whose rearing techniques are considered to have been fully developed. Since this species' growth is highly temperature-dependent, it was hoped that it would respond well to the transfer from the Mediterranean to the environment of Martinique. This was indeed so until an unknown virus wiped out the AQUAMAR farm's stock.

This virus and the lack of knowledge at the time on how to reduce the mortality rate forced the company to close down. This affected potential local investors who turned their backs on aquaculture.

It is worth noting that the same strategies are currently being implemented in Cuba, where a European industrial farm is rearing European sea bass and gilt-head bream (*Sparus auratus*). The pathological obstacles have been overcome, but other biological and technical problems have emerged, such as early ripening which hinders rapid growth, resulting in products of less than expected value.

Diversification trials

Phase two involved trials in Martinique's two experimental stations, IFREMER and ADAM (Association for the Development of Aquaculture in Martinique). Several local species were tested as well as the introduced species, red drum.

Red drum proved to be a much higher-performance species in terms of growth and hardiness, and in the initial stages of domestication. In 1993, it was felt that sufficient knowledge had been gained to justify its development (Goyard and Falguière, 1993). ADAM established a pilot-farm for growing-out and, in 1996, designed and set up a hatchery in order to meet the needs of the first aquaculturists.

In 1997, an industrial company was set up in Martinique providing a new outlet for local fish farming, with Martinique adopting a two-pronged approach: a small-scale sector supplying the local market, and an "industrial" sector, which had to be competitive on the Metropolitan French market, as well as on the international market generally (Houel *et al.*, 1996). Meeting requirements in terms of fingerlings depended on the production capacity of the ADAM hatchery, which benefited from IFREMER's research findings.

This set-up proved inadequate to enable the red drum sector to take off. Fry production was irregular, not to say non-existent, and all the technical operations were risky (absence of materials in Martinique and the need to import them from Metropolitan France, lack of cash, lack of know-how and lack of operational synchronisation). Red drum production remained small and was too sporadic to give the product a stable position on the local market. None of the companies were economically viable and requests to establish new companies were few and far between.

At that time, IFREMER and ARDA (Association for Aquaculture Research & Development) developed an assistance programme for Reunion Island. First, eggs were sent, followed then by larvae for hatching, thus enabling a fish stock to be established. The local hatchery in Mayotte provided the material both for the initial experiments and for an industrial development which began production in 2000 (300 tonnes in 2002).

Reactivating the Production Chain

It is clear that until 2001 there were too few players involved in the sector to enable both rearing and marketing to be carried out. Taken separately, each segment of the sector requires know-how, but the sector can operate only if these segments are well synchronised, which is all too rarely the case.

Therefore, in an effort to simplify operations, IFREMER proposed putting their experience, acquired with ARDA's help, into practice: the Institute has a sizeable breeding stock from several genetic sources and is able to schedule spawning several times a year at precise dates and to supply users directly with larvae for hatching. The taking over of these operations by the Institute allowed the sector to concentrate on the other activities. A test carried out in late 2001 produced almost 120 000 juveniles, a sufficient quantity given the current number of aquaculturists.

In 2002, the test was carried out once more. Six new growing-out enterprises had been established and three larval rearing workshops were in operation. Projections for 2003 point to the creation of four new grow-out enterprises and one new larval rearing facility.

Aquaculture products are highly appreciated on the local market and there have been no marketing problems to date, as the products are backed up by advertising campaigns promoted by the producers.

Technical Know-How

Rearing techniques may be divided into four complementary operations:

- good growth and survival in intensive rearing up to marketing size
- monitoring of juvenile production
- controlled breeding in order to obtain programmed spawning
- sustainable management of breeding stock.

Growth and Survival

Fry growth and survival rates are shown in the table below (Houel et Paquette, 1996).

Weight obtained (g)	Rearing time (d)	Survival (%)	Stocking density (kg/m ³)
350	158	85	30
800	245	79	30

The growth curve in Figure 2 refers to the first year of rearing (Buchet *et al.*, 1999).

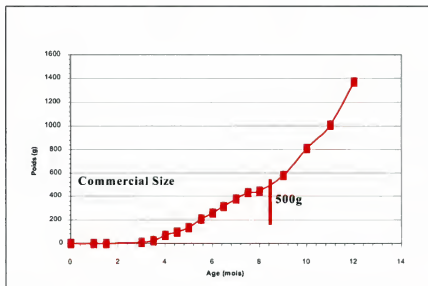


Figure 2. First year rearing growth curve of red drum in Martinique (IFREMER, 2001).

The fish are given industrial feeds, formulated for sea bass (*D. labrax*), but recently modified for red drum. The conversion index is 1.8.

The smallest marketed size (350g) is what is termed “food size”. This is the size distributed to restaurants and to some private consumers. The 800 g fish are not as common, but this is the size in greatest demand for family meals and parties. This is also the size preferred by fish farmers as fish of this size are not commonly found in West Indian seafood markets. It also reduces fingerling costs in terms of one kilo of marketed fish - still a very costly item. On the other hand, fish farmers are obliged to retain the fish for longer, which ties up space in the cages and reduces the frequency of fish deliveries to market.

Juvenile Production

The juvenile production technique was developed in the early eighties (Arnold *et al*, 1979, Chamberlain *et al*, 1987). However, this technique had to be modified to suit Martinique's environmental conditions and available technical facilities (Goyard *et al*, 1993). It is updated regularly (Dudognon et Parry, 2002). A summary of the technique is given in Table 1 below.

Table 1. Characteristics of red drum larvae rearing.

Larvae rearing density:	50 to 100/litre	
Feeding:	From Day-2 to Day-12	= rotifers
	From Day10 to Day-18	= artemia
	Weaning from Day-15	
Larvae survival:	10 to 40 % for a juvenile of 2g	
Duration of larval rearing:	50 to 70 days	
Mortality mainly due to:	Cannibalism	

Generally speaking, juvenile production is carried out by hatcheries which monitor the degree of egg ripeness in the breeding stock by means of ovary biopsies. One tank contains both males and females ; the eggs are laid and then fertilised. They float to the surface and can then be easily collected and placed in an incubator.

Martinique's existing facilities can deal with hundreds of thousands of eggs and have the capacity to rear 100 000 to 200 000 juveniles. The final days of rearing are particularly demanding in terms of facilities (200 to 400 kg of fry). These quantities are sufficient for the current level of mariculture, but generate high fry production costs.

Controlling the Breeding Process

Red drum has only one natural breeding season. Depending on the geographical area, the species spawns between August and October, with egg ripening dependent upon environmental conditions, mainly shorter day length and lower water temperature (Arnold *et al*, 1979). The effect of water temperature has been shown to be negligible under local conditions.

The equipment available in the IFREMER station's controlled photoperiod rooms has allowed us to adapt the techniques (Goyard *et al*, 1993). In 1995, the IFREMER station had two separate conditioning rooms (Buchet *et al*, 1999), each comprising one 16 m³ trough with a water recycling device (Figure 3). The current process (Figure 4) is based on constant lighting for 16 hours/day, falling by 5 ½ hours in two months, with a low exposure time of 10½ hours for two further months, during which the ripening process comes to an end and the eggs are laid. At the end of the season, the photoperiod is increased and the fish become sexually dormant for the remainder of the year (Gardes *et al*, 2000).

The IFREMER station was fitted with a third conditioning room in 2001 and can now have three spawning seasons per year.

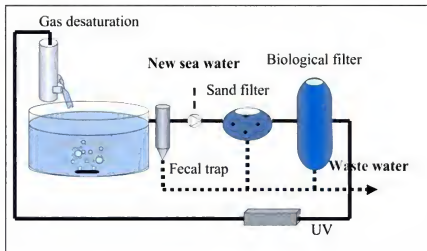


Figure 3. Broodstock conditioning tank under light control.

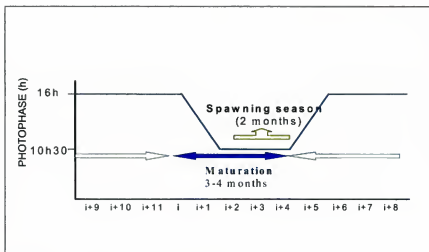


Figure 4. Conditioning cycle of broodstock.

Sustainable management of breeding stock

Since red drum's initial introduction in 1985, followed by further regular introductions in 1987, 1990, 1996, 1998 and 1999, we have not observed breeding in the Martiniquan environment either by fish maturing naturally in cages or by fish that have escaped from the fish farms.

Aquaculture depends, therefore, on having a captive breeding stock and ensuring its sustainability:

- by preventing in-breeding through fish selection;
- by using broodstock derived from different genetic stock.

Spawners are identified individually and fitted with a magnetic tag. Work was carried out in 2001 and 2002 at the IFREMER station with a view to selecting the breeding stock individually and isolating them in pairs (Usache *et al.*, 2002). This is the first step towards the establishment of genetic research programmes.

Care must also be taken to prevent the introduction of pathogens. Due to a better understanding of nodavirus and the development of a sensitive screening system, (Lancelot, 2002), the station's red drum larvae have, since 2002, undergone an ELISA test prior to dispatch to the fish farmers.

Development Phases

Mariculture development can be divided into three successive phases (Figure 5).

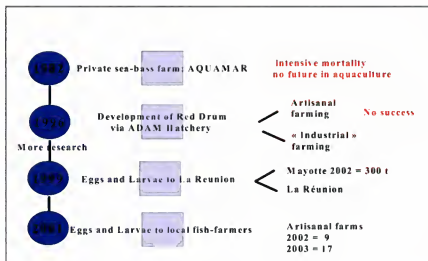


Figure 5. History of fish farming development.

IFREMER's Role

IFREMER's role includes conducting and promoting basic and applied research, as well as taking technical steps to promote the economic development of aquaculture. Consequently, the organisation of the mariculture laboratory was reviewed with a view to using the existing breeding stock to improve knowledge (thematic research), increase the production of eggs and, even more importantly, increase the production of larvae for hatching.

To this end, the fish stock was divided into three separate lots in an effort to achieve spawning three times a year, with the dates decided after discussion with the producers. The composition of the lots was reviewed so as to increase the number of hen fish per pond in 2003, thereby ensuring that the rearing workshops' larvae requirements are met. (Figure 6).

An aquaculturist helped to convert a larval rearing workshop for a small-scale enterprise. The workshop consists of a concreted area between two disused tanks. One tank has been prepared for rearing live prey and the larvae are kept in 800 litre tubs on the concreted area, protected from the light by a canopy. The existing seawater network (pumps, filters and distribution system) was carefully examined. The workshop has already conducted four rearing operations and can now supply the enterprise with juveniles (Figure 7).

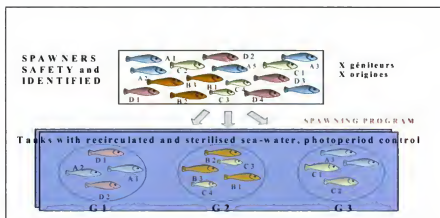


Figure 6. Management of spawning stock.



Figure 7. Artisanal hatchery: Aquanord Caraïbes.

Given the risk of viral pathogens as found in red drum farms in the Indo-Pacific, special attention has been paid to health conditions. The breeding stock are kept in closed systems with UV sterilisation of the reeyeled water, and ELISA tests are carried out on the larvae prior to dispatch to outside workshops (Figure 8).

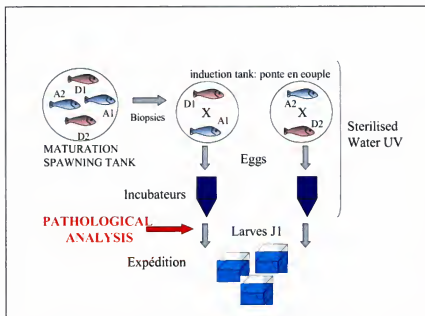


Figure 8. Planning of the spawning process.

Research programmes have attached top priority to breeding physiology. The aim is to control fertilisation between isolated pairs to enable selection of the breeding stock (this reduces the risk of in-breeding in the ponds and helps in the preparation of genetic programmes).

All the operations are to be covered by a protocol, currently being prepared by the producers, Martinique Region and IFREMER. It will apply for a period of 3 years to secure the sector's start-up.

Regional Cooperation

Red drum mariculture is now operational in Martinique. It is a small-scale aquaculture operation largely geared to small family-run enterprises. Initial economic viability calculations suggest a production threshold of about 15 tonnes/year/enterprise under Martinique's socio-economic conditions.

The Martiniquan model deserves to be extended to other Caribbean countries. This model relies on one larval production unit which supplies the enterprises. Product distribution is

easy, transport conditions are well-known and the air transport between the islands is well-developed. The first implementation of this model is starting in Guadeloupe. There, local development may be restricted to larval rearing workshops and grow-out - simple operations of relatively short duration (two months for larval rearing and 5 months for grow-out). A first co-operation trial is planned between Martinique and Cuba.

The prerequisite for technical trials must be a technical/economic feasibility study. Living standards differ from one island to another and there will be wide disparities between the price of materials, labour costs and marketing prices.

A cooperation programme should not only cover the technical aspects of fish farming, but deal with all matters regarding feasibility (administrative constraints, the presence of suitable sites, coastal development options, training for fish farmers and technical and financial assistance

Acknowledgements

Special mention must be made of Martinique Region for its special and sustainable efforts to promote mariculture. IFREMER's research programme in support of the aquaculture sector is co-funded by the Region.

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TILAPIA PRODUCTION SYSTEMS FOR THE LESSER ANTILLES AND OTHER RESOURCE-LIMITED TROPICAL AREAS¹

by

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INTRODUCTION

There are many areas in the tropics that do not have the right combination of resources (i.e., water supplies, soil type or topography) to culture tilapia by standard dug-pond techniques. The Lesser Antilles, a group of Eastern Caribbean Islands, is one such area. The relatively dry Leeward Islands have insufficient water for pond culture and their porous caliche soils do not retain water. The rugged Windward Islands generally lack suitable level terrain for a large expanse of dug ponds.

There is a need for cultured fish in the Lesser Antilles to offset declines in the fisheries sector (de Graaf and Moore 1987). To supply seafood to local and tourist markets, the Caribbean Community and Common Market (Antigua and Barbuda, Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Jamaica, Montserrat, St. Lucia, St. Kitts and Nevis, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago) imported US\$84 million worth of fisheries products in 1996 (FAO 1998). Tilapia is the ideal culture fish to increase local supplies in the Lesser Antilles because it can be cultured at high densities in systems that are feasible with limited resources. Although West Indians traditionally consume only marine finfish, they will accept tilapia as a substitute. Moreover, there is large tourist market for tilapia because resort restaurants cannot depend on consistent supplies of marine finfish.

The University of the Virgin Islands (UVI) has developed three tilapia culture systems that are appropriate for the Lesser Antilles and other resource-limited, tropical areas. The systems are cage culture in small watershed ponds, greenwater tank culture and aquaponics, the combined culture of fish and hydroponic plants in recirculating systems. Research on the commercial development of the latter two systems is ongoing. Therefore, this paper will be a summary of the cage culture work and a progress report on the development of greenwater tank culture and aquaponic systems.

Cage Culture in Small Watershed Ponds

The Leeward Islands have no running water except for a few days after major rainstorm events, which occur about once a year. Many small watershed ponds have been constructed to

¹ This is a revision of a paper that was originally published in the proceedings of a symposium: pages 651-662 in K. Fitzsimmons and J. Carvalho Filho, Eds. *Tilapia Aquaculture in the 21st Century: Proceedings from the Fifth International Symposium on Tilapia in Aquaculture*, Rio de Janeiro, Brazil

store runoff water for agricultural use and groundwater recharge. New ponds often have high seepage rates and dry quickly. Eroded clay and organic matter eventually seal the ponds, some of which hold sufficient water year round for cage culture while others retain water long enough for one cage crop.

Since the ponds range in size from 0.1 to 2 ha, small cages are required. All of the cage culture studies at UVI utilized 1-m³ cylindrical cages constructed of semi-rigid plastic screen (1.9-cm mesh) tied onto steel hoops. This mesh size facilitated maximum water exchange between the cage and the pond. The cages were 1.22 m high and 1.06 m in diameter and floated with approximately 10 cm of freeboard. A feeding ring was suspended from the cage top to a depth of 51 cm (Figure 1).



Figure 1. Small cage (1 m³) for tilapia culture showing demand feeder and feeding ring.

Cages were deployed in the deepest section of the pond in an area with the greatest exposure to wind and currents. Cages were individually anchored at least 2 m apart. Since smaller ponds could support only four to six cages, the twice-daily feeding became too time consuming for farmers with diversified operations. The farmer would have to deploy a small boat and row to the cage to administer floating feed. Following a fixed-rate feeding schedule was not practical for small operations and the fish were often overfed or underfed. Therefore, an inexpensive demand feeder was developed and tested (Hargreaves et al. 1988). The demand feeder consisted of an 18.9-L plastic bucket into which a polyethylene funnel was inserted (Figure 2). The feeder was mounted on the cage top and could be activated by a brass rod suspended from the funnel into the cage. When demand feeders were compared to a fixed-rate feeding schedule, there was no significant difference ($P > 0.1$) in growth rate, and in two out of three experiments marketable production was significantly higher and the feed conversion ratio (FCR) was significantly lower ($P < 0.1$) with demand feeders as compared to a fixed-rate feeding schedule. The most important finding was that demand feeders reduced labour by 88 to 94%. The demand feeders were filled on average every 4.3 days to 7 days in the three experiments. Reduction in labour made small operations feasible.



Figure 2. Commercial cage culture operation in St. Croix, U.S. Virgin Islands.

An experiment was conducted in a 2-ha pond to evaluate five species/strains of tilapia stocked at 300 fish/cage (1 m^3) and fed with the demand feeders (Rakocy et al. 1993a) (Figure 2). The species/strains were *Oreochromis niloticus* (Ivory Coast strain), *Oreochromis aureus*, a modified Florida red tilapia from Jamaica, an Aurea red tilapia (95% *O. aureus* heritage bred into Florida red tilapia) and Taiwan red tilapia. Using sex-reversed male fingerlings, the fish were allowed to feed on nutritionally-complete floating pellets (36% protein) for 143 days. The best-performing species/strain was *O. niloticus*. It grew from 73 g to 616 g, a daily weight gain of 3.8 g/day. Final cage biomass, FCR, and survival were 182 kg, 1.30 and 97.7%, respectively. Among the red tilapia the modified Florida red and the Aurea red tilapia performed equally well with daily weight gain of 3.5 and 3.3 g/day, final cage biomass of 163 and 161 kg, FCR of 1.45 and 1.30, and survival of 93.3 and 98.3%, respectively. Since West Indians prefer colourful fish that resemble familiar marine species, the modified red tilapia was selected for future research. The Aurea red tilapia was discontinued due to the difficulty of maintaining this cross.

The next experiment evaluated the effects of four levels of diffused aeration (one air stone per cage activated for 0, 6, 12 or 24 hours/day) in the cages and two stocking densities (400 and 600 fish/ 1-m^3 cage) on the culture performance of red tilapia (Hargreaves et al. 1991). Using demand feeders, a nutritionally-complete floating pellet was fed for 143 to 146 days. Diffused aeration had no significant ($P > 0.05$) effect on fish growth, survival, feed conversion and production in cages. Combined across all levels of diffused aeration, fish stocked at 400/cage had a significantly greater growth rate (2.21 vs. 1.97 g/day), larger final body weight (370 vs. 335 g) and lower feed conversion ratio (1.69 vs. 1.80) than fish stocked at 600/cage ($P < 0.05$). The final biomass of fish stocked at the higher density (181 kg/m^3) was greater than that at the lower density (140 kg/m^3). Increased water exchange rates by diffused aeration did not lead to increased tilapia growth or production.

Enterprise budgets were prepared from the growth and production data of red tilapia stocked in 1-m³ cages at three densities (300, 400 and 600 fish/m³) (Bailey et al. 1989). The previous experiments showed that fish growth rate, final body weight, survival rate and feed conversion efficiency were inversely related to stocking density. Therefore, annual return to risk for a hypothetical cage culture enterprise in a 2-ha watershed pond with production capacity assumed to be 3,000 kg/ha/crop was higher at 300 fish/m³ (\$41,506) than at 400 fish/m³ (\$35,439) or 600 fish/m³ (\$30,745). High growth rates at low density and the use of less male fingerlings improved feed conversion efficiency, reduced cost and allowed the production of more large fish of higher value, thereby increasing revenue. Assumed value of red tilapia was \$5.50/kg for fish > 454 g and \$4.40/kg for fish < 454 g. The breakeven price was \$2.71/kg at a density of 300 fish/m³. Given the relatively minimal labour requirements of the production enterprise and the modest investment required (\$125 per cage with demand feeder), a farmer can significantly increase farm revenues by adding cage culture to the farm business.

Using different assumptions, a second economic analysis was performed for the production of red tilapia on a staggered schedule in a 2-ha pond and in batches in a 0.4-ha pond that retains water intermittently (6 months per year) (Bailey and Rakocy 1992). All stages of production would occur in the 2-ha pond and would require nine hapas and 49 cages of variable mesh size for breeding, sex reversal, three stages of fingerling rearing and growout. The growth stages would require different feeds. Staggered production would involve considerably more labour than needed in the previous analysis, but it represents a more realistic production system for small islands where markets demand agricultural products on a consistent basis. Harvests of 545 kg would occur biweekly, and annual production would be 14,182 kg. Net cash flow would range from \$27,780 in year 2 to a high of \$29,852 in year 15 out of a 20-year projection. The net present value at 20% and internal rate of return would be \$28,279 and 27%, respectively. In the 0.4-ha pond, annual production would be 1090 kg. The annual net cash flow would be \$4,218 over a 5-year period. Net present value at 20% and internal rate of return would be \$10,988 and 259%, respectively. With this scenario, the farmer would have to store the cages in a shelter during the dry season and purchase fingerlings when the pond fills. This analysis shows that even a small cage culture facility, operated during high water periods, can supplement a farmer's income.

Implementation of cage culture in small watershed ponds would increase dramatically if a supply of tilapia fingerlings were available. If island governments choose to promote tilapia aquaculture, they may have to invest in a hatchery for the initial production of tilapia fingerlings, for sale to farmers. As an industry develops, fingerling production should eventually be transferred to the private sector. Jamaica followed this strategy in the development of their tilapia industry, which developed on a much larger scale than envisioned for the Lesser Antilles.

There are some important factors to consider in planning cage culture operations in small ponds. One factor is the production capacity of the ponds. Earthen ponds can generally assimilate the waste generated from a maximum feeding rate of approximately 50 kg/ha/day without the need for emergency aeration. With fish constricted to high densities in cages and more dependent on high dissolved oxygen (DO) levels than open-water fish, the maximum feeding should not exceed 25 kg/ha/day for extended periods to ensure adequate water quality. The pond will be most productive with a staggered production system whereby the feed is consistently administered near the maximum feeding rate.

Another factor to consider is the need for emergency aeration after major rainstorm events. Between major rainstorm events pond levels gradually decline and shoreline vegetation proliferates. Excessive rain and runoff will flush phytoplankton from the pond and submerge shoreline vegetation, which slowly decays and depletes DO by the ninth or tenth day after the storm. This phenomenon was observed repeatedly in St. Croix. An emergency aeration system is necessary for 3 to 4 weeks after ponds refill with runoff water.

A final factor to consider is the susceptibility of caged fish to theft. Cages deployed in isolated ponds often prove to be an irresistible temptation. Ponds should be secured to the greatest extent possible and cages should be situated in a manner that makes theft difficult. In St. Croix, cages were attached to yacht rigging, which cannot be cut with normal wire cutters, and anchored individually in the deepest water with two concrete blocks. Nevertheless, some theft occurred. Whatever makes cages easily accessible to farmers will also benefit thieves.

Greenwater Tank Culture

UVI initiated research on greenwater tank culture of tilapia because production levels are substantially higher than ponds, water seepage problems are avoided and commercial levels can be achieved with relatively limited water resources. Variations of greenwater tank culture are used in Israel (Avnimelech 1998), Louisiana (Lutz 1998) and California (Sehroeder and Serfling 1989).

The process whereby metabolic waste products of fish are treated in greenwater tank culture, allowing productivity increase, is alternately referred to as a suspended growth process, an activated suspension process or a bioconversion process. Regardless of name, the principle is the same and involves the oxidation of toxic ammonia and nitrite to relatively non-toxic nitrate ions by nitrifying bacteria attached to suspended organic matter. Additional removal of ammonia occurs through direct uptake by phytoplankton. Organic wastes are incorporated into bacteria or respired as carbon dioxide. The rich microbial populations of greenwater tank systems provide nutrition to tilapia and improve feed conversion efficiency. Most greenwater systems remove settleable solid waste daily while some add a fixed-film nitrification unit to supplement the biofiltration that occurs in the water column. Greenwater tank systems must be aerated to sustain adequate DO levels in tanks with elevated organic loading and correspondingly higher biochemical oxygen demand (BOD).

A major advantage of greenwater tank systems is that water treatment is based primarily on bacteria. In ponds, water treatment is based mainly on phytoplankton. An algal die-off in ponds leads to oxygen depletion, necessitates emergency aeration and disrupts feeding and production. An algal die-off in greenwater tanks has relatively minor impact. Mechanical aeration continues to supply sufficient oxygen and bacteria continue to oxidize toxic waste metabolites. Dead algae settle to the tank bottom and are eliminated through daily sludge removal, thereby reducing BOD and avoiding secondary ammonia production.

Greenwater tank culture research at UVI is conducted in circular fiberglass tanks that are 6 m in diameter and 1.22 in height. Water volume averages 30 m³. The tanks are continuously aerated by a 1/20-hp vertical lift pump and 13 air stones (7.6 cm x 3.8 cm x 3.8 cm). The rearing tank floor has a 3° degree slope to a central drain. Water is drawn from the rearing tank by an airlift pump into a 1.4-m³ cylindro-conical clarifier with a 45° bottom slope. Each clarifier is stocked with 10-15 male tilapia fingerlings to graze algal growth and facilitate the settling of solids. Two baffles are placed perpendicular to the water flow. The central baffle

extends the height of the cylinder. Flow rate is maintained at 20 L/min so that the entire rearing tank volume passes through the clarifier once every 24 hours. The clarifier residence time is 70 minutes. Concentrated solids (sludge) are removed and volumetrically measured twice daily from each clarifier.

Six experiments were conducted in greenwater tanks. All experiments except one included two treatments with three replications per treatment. In the first experiment, male red tilapia (mean wt. = 46 g) were stocked at 8 and 16 fish/m³ and cultured for 20 weeks using a 32% protein floating feed at 4% body weight initially, a rate that was gradually reduced (Cole et al. 1994). Mean fish growth rates of both treatments were 2.8 g/day. Mean yield, survival and feed conversion were 2.9 kg/m³, 93% and 1.7 at the low density (LD) and 5.9 kg/m³, 95% and 1.6 at the high density (HD). There were no significant differences ($P > 0.05$) and the production capacity of the system was not reached. The clarifiers were very effective at removing dead algal cells as indicated by substantially higher chlorophyll *a* concentrations in the sludge than in the water column. Substantial nitrification occurred in the water column as indicated by nitrate levels, which increased from 2.9 to 60.0 mg/L in the LD systems and 2.9 to 121.7 mg/L in the HD systems. The rearing water and sludge, which were used in an experiment to irrigate and fertilize bell peppers, compared favourably with inorganic fertilizers. Levels of total phosphorus at 20 weeks were 12.3 mg/L (LD), 21.5 mg/L (HD) and 90.0 mg/L (sludge).

A second experiment was conducted to determine the effect of a 5% daily water exchange and no water exchange on tilapia production (Cole et al. 1994). Male red tilapia (mean wt. = 94 g) were stocked at 12 fish/m³ and cultured for 24 weeks. Daily water exchange was initiated after week 8. Mean growth rates, yields, survival and feed conversion were 3.5 g/day, 6.8 kg/m³, 97% and 1.8 for water-exchange tanks and 3.4 g/day, 6.5 kg/m³, 95% and 1.9 for tanks without water exchange. Yields were larger than those in the first experiment due to the use of larger fingerlings and a longer culture period. A 5% daily water exchange did not significantly improve ($P > 0.05$) any of the production parameters. The sludge was used to irrigate bell peppers, which performed better with sludge (total fruit yield of 15.1 mt/ha) than with inorganic fertilizers applied at 100 kg/ha of P and K and 200 kg/ha of N in the irrigation water (10.5 mt/ha). The application of sludge resulted in the addition of 28 kg/ha of inorganic nitrogen, 913 kg/ha of organic nitrogen and 122 kg/ha of total phosphorus.

The stocking rate was increased in the third experiment to 24 fish/m³ (mean wt = 16.5 g) using male red tilapia (Cole et al. 1995). The fish were fed for 24 weeks. Sludge was removed twice daily from one set of tanks (SR). In another set of tanks the clarifier was disconnected and sludge was not removed (NSR). Growth rate, final weight and final biomass were significantly higher ($P < 0.05$) in the SR tanks (2.4 g/day, 422 g, 9.0 kg/m³) than in the NSR tanks (2.1 g/day, 364 g, 7.6 kg/m³). There were no significant differences in survival, feed conversion, DO, total ammonia-nitrogen (TAN) or nitrite-nitrogen. The final concentration of total suspended solids was significantly higher in the NSR tanks (1,250 mg/L) compared to the SR tanks (368 mg/L). Although mean chlorophyll *a* levels were significantly higher in the NSR tanks (1029 µg/L) than in the SR tanks (655 µg/L), phytoplankton appeared healthier in the SR treatment as dead or clumped algal masses were quickly removed. Two crops of pak choi were raised using rearing tank water, sludge and standard fertilization treatments. The culture water and sludge were comparable or better than standard fertilization techniques.

The third experiment was repeated using male *Oreochromis niloticus* (mean wt. = 71 g), stocked at 26 fish/m³ and fed for 24 weeks (Cole et al. 1997). The treatments were solids removal (SR) twice daily and no solids removal (NSR). Growth rate, final weight, final biomass and feed conversion ratio were significantly better ($P < 0.05$) in the SR tanks (2.6 g/day, 514 g, 13.4 kg/m³, 1.4) than in the NSR tanks (2.1 g/day, 417 g, 10.8 kg/m³, 1.5). Solids removal did not affect survival (overall mean = 99.1%). Nile tilapia performed better in the system than the red tilapia in previous experiments. Solids removal did not significantly affect DO, temperature, TAN or nitrite-nitrogen. Combined treatment means were 6.5 mg/L, 25.7°C, 0.82 mg/L, and 2.99 mg/L. Nitrite-nitrogen removal is less efficient with a suspended growth process than TAN removal. However, any harmful effects of nitrite-nitrogen were mitigated by high levels of chloride ions (108 mg/L) in the groundwater source. If the source water has low chloride concentrations, a preventive treatment with calcium chloride is recommended. The amount of water required to produce 1 kg of tilapia was 0.2 m³ in both treatments. Per 1 kg of feed input, the clarifiers removed 325 g of total solids, 38 g of BOD, 18 g of total nitrogen and 5 g of total phosphorus. The sludge, which was used to irrigate and fertilize guineagrass forage, performed significantly better than a standard inorganic fertilizer treatment. An advantage of the sludge is that it has a long (>1 year) residual fertilizer effect.

The fifth experiment (unpublished data) was a non-replicated preliminary trial to evaluate the effect of three levels of weekly alum (aluminium sulphate) addition on tilapia production. Male Nile tilapia (mean wt. = 197 g) were stocked at 17.8 fish/m³ and fed *ad libitum* for 25.6 weeks. Weekly additions of alum were 25.8, 38.7 and 51.5 mg/L. Respective results were 4.35, 4.41 and 4.66 g/day for growth rate, 947, 954 and 1,002 g for final size, 16.0, 16.3 and 17.1 kg/m³ for final biomass and 1.79, 1.86 and 1.87 for feed conversion ratio. Growth rate, final size and final biomass were substantially higher than results obtained in previous experiments due to a much larger fingerling size, a longer production period and modification of the feeding method to better reflect demand. It appeared that higher alum application led to higher production. The total amount of sludge generated was 11.6, 12.5 and 17.1 m³ for weekly alum applications of 25.8, 38.7 and 51.5 mg/L.

The sixth experiment (unpublished data) employed replicated treatments to determine if weekly additions of 50 mg/L of alum affect tilapia production. Male Nile tilapia (mean wt. = 41.5 g) were stocked 24 fish/m³ and fed *ad libitum* for 30 weeks. Growth rate, final weight, final biomass and feed conversion ratio were 3.4 g/day, 744 g, 17.0 kg/m³ and 1.56 for the non-alum treatment and 2.8 g/day, 629 g, 14.5 kg/m³ and 1.55 for the alum treatment, respectively. The results were not significantly different ($P > 0.05$). There was no significant difference in total sludge production, TAN and nitrite-nitrogen between the non-alum (12.7 m³, 2.7 mg/L, 2.0 mg/L) and alum (13.8 m³, 3.8 mg/L, 4.6 mg/L) treatment, respectively. Nitrate-nitrogen was significantly ($P < 0.05$) higher in the non-alum treatment (156.9 mg/L) than in the alum treatment (104.0 mg/L) while DO was significantly lower in the non-alum treatment (5.6 mg/L) than in the alum treatment (6.5 mg/L). It appears that the application of alum increased the removal of suspended organic matter and its associated nitrifying bacteria, which resulted in higher concentrations of TAN and nitrite-nitrogen and lower levels of nitrate-nitrogen. Lower nitrate-nitrogen levels indicate that there was less nitrification. By removing more organic matter and BOD, the alum treatment produced higher DO levels. Although the results were not significant, it appeared that alum decreased tilapia production.

With greenwater tank culture feeding response appears to fluctuate more than it does with pond culture. A practical method has been devised to feed at the correct rate. On Mondays,

Wednesdays and Fridays the fish are fed *ad libitum* for 30 minutes at 0900 and 1600 hours. The rate established on those days is used on the following day, or, in the case of Fridays, the next two days. This method has been successful in conforming to the feeding response as evidenced by a low feed conversion ratio of 1.56 for 744-g tilapia. The fish occasionally go off-feed for several days for unknown reasons. The off-feed response cannot be attributed to DO, TAN or nitrite, which are generally at acceptable levels. Off-feeding may be due to the temporary accumulation of some organic breakdown product that is detrimental to the fish. An experiment is now in progress to determine if one large dose of alum (100 mg/L) at the beginning of an off-feeding cycle can purge of system of the parent material from which the detrimental dissolved organic compound is derived, thereby shortening the cycle. The addition of 1 kg of alum will destroy 0.5 kg of alkalinity. Therefore, when adding alum to a greenwater system, it is important to monitor alkalinity and add base.

The greenwater tank has been scaled up to a commercial size for small islands. A 200-m³ tank has been constructed using a block wall and a high-density polyethylene liner (Figure 3). The tank is 16 m in diameter and 1 m in depth. A 1-m³ clarifier with a 45° slope has been incorporated in the centre of the tank floor, which has slope at 3° from the sidewall to the centre clarifier. A vertical-lift pump has been tilted on its side to establish a circular flow pattern, which moves settleable solids to the clarifier. Solids are removed by opening an external standpipe. If two crops per year can be produced at a final density of 17 kg/m³, this tank will produce 6,800 kg of tilapia annually (Figure 4). Producing a comparable amount of tilapia by pond culture would require 25 to 30 times more water and land.



Figure 3. Commercial-scale greenwater tank (200 m³) at UV1 (St. Groix).



Figure 4. Nile tilapia produced in a greenwater tank culture system.

Aquaponic Systems

Aquaponic systems require very little water and land for the intensive production of tilapia, hydroponic vegetables and other crops such as culinary herbs, medicinal herbs and cut flowers. The fish provide adequate quantities of most of the nutrients required for plant growth. The nutrients are excreted directly by the fish or generated through the mineralization of organic waste. The plants utilize these nutrients to produce a valuable by-product and improve the system's profit potential. The hydroponic component also serves as a biofilter, removing ammonia through direct uptake by plants and through oxidation of ammonia and nitrite by nitrifying bacteria that grow on the tank surface area. A very stable balance is reached between nutrient generation and water treatment, which eliminates the need for the intensive water quality monitoring required by non-integrated systems. By removing nutrients, hydroponic plants extend water use and reduce discharge to the environment.

Aquaponic research at UVI began with six replicated systems that consisted of a rearing tank (12.8 m^3), a cylindro-conical clarifier (1.9 m^3), two hydroponic tanks (13.8 m^3) and a sump (1.4 m^3) (Rakocy 1997). The hydroponic tanks (6.1 m long by 1.22 m wide by 28 cm deep) were initially filled with gravel supported by wire mesh above a false bottom (7.6 cm). The gravel bed, which served as a biofilter, was alternately flooded with culture water and drained. Due to the difficulty of working with gravel, the gravel was removed and a raft system, consisting of floating sheets (2.44 m long x 1.22 m wide x 3.8 cm thick) of polystyrene, was installed. A rotating biological contactor (RBC) was then used for nitrification. Effluent from the clarifier was split into two flows, one going to the hydroponic tanks and the other to the RBC. These flows merged in the sump, from which the treated water was pumped back to the rearing tank.

The rearing tank in this design proved to be too large relative to the plant growing surface area of the hydroponic tanks, or, conversely, the hydroponic tanks were too small relative to the size of the rearing tank. When the rearing tank was stocked with tilapia at commercial rates, nutrients rapidly accumulated to levels that exceeded the recommended upper limits for hydroponic nutrient solutions [2,000 mg/L as total dissolved solids (TDS)] (Rakocy et al. 1993b). Using Bibb lettuce, the optimum ratio between the fish feeding rate and plant growing area/day) the nutrient accumulation rate decreased and the hydroponic tanks were capable of providing sufficient nitrification. Therefore, the RBCs were removed and the fish stocking rates were reduced to levels that allowed feed to be administered near the optimum rate for good plant growth.

The experimental system has been scaled up three times. In the first scale-up, the length of each hydroponic tank was increased from 6.1 m to 29.6 m. The optimum design ratio was used to allow the rearing tank to be stocked with tilapia at commercial levels (for a diffused aeration system) without excessive nutrient accumulation. In the second scale-up, the number of hydroponic tanks (29.6 m in length) was increased to six; the number of fish rearing tanks was increased to four (each with a water volume of 4.4 m³); the number of clarifiers was increased to two; four filter tanks (0.7 m³ each) were added and the sump was reduced to 0.6 m³. This production unit, commercial aquaponics 1 (CA1), represented a realistic commercial scale, although there are many possible size options and tank configurations. The final scale-up, commercial aquaponics 2 (CA2), involved the enlargement of the four fish rearing tanks (each with a water volume of 7.8 m³) and the two clarifiers (each with a water volume of 3.8 m³) and the addition of a 0.7-m³ degassing tank (Figures 5 and 6). The commercial-scale units could be configured to occupy as little as 0.04 ha of land.



Figure 5. Commercial-scale aquaponic system producing a crop of basil at UVI (St. Croix).



Figure 6. Commercial-scale aquaponic system at UVI (St. Croix) showing (counterclockwise) rearing tank (top right), clarifier, filter tanks, degassing tank and return sump.

The rearing tanks and water treatment tanks were situated under an opaque canopy. This inhibits algae growth, lowers water temperature, which is beneficial for hydroponic plant production, and creates more natural lighting conditions for the fish.

The system uses multiple fish rearing tanks to simplify stock management. Tilapia production is staggered in four rearing tanks so that one rearing tank is harvested every six weeks. The fish are not moved during their 24-week growout cycle. In a 2.5-year production trial in CA 1 using sex-reversed red tilapia, annual production was 3,096 kg, based on the last 11 harvests out of 19 harvests (Rakocy et al. 1997). Fingerlings, stocked at 182 fish/m³, grew at an average rate of 2.85 g/day to a size of 487 g. The final biomass averaged 81.1 kg/m³. This is equivalent to annual production of 175.7 kg/m³ of rearing tank space. The average feed conversion and survival were 1.76 and 91.6%.

The stocking density appeared to be too high for maximum growth and efficient feed conversion. Midway through each production cycle, *ad libitum* feeding levelled off at approximately 5 kg per rearing tank. As the fish grew in the last half of the production cycle, feed consumption did not increase. Therefore, more of the feed was used for maintenance and less was used for growth, leading to a relatively high feed conversion ratio for 487-g fish. In CA2 the stocking rate for red tilapia has been lowered by 15% to 154 fish/m³. The growth of Nile tilapia is being evaluated at a stocking rate of 77 fish/m³ with a goal of producing 1-kg fish for the fillet market. With larger rearing tanks and higher growth rates, it is anticipated that CA2 will produce 5 mt of tilapia annually.

The production trial employed two methods of *ad libitum* feeding. A demand feeder, used initially, was replaced by belt feeders, utilizing variable quantities of feed adjusted to meet the demand. Neither method proved to be entirely satisfactory. With demand feeders, high

winds would shake the feeder, which then dispensed too much feed, or clumps of feed would block the funnel opening of the demand feeder, which then delivered too little feed. The belt feeders periodically failed, not delivering any of the day's ration. Both devices are expensive and require support structures. In CA2 the fish are fed *ad libitum* by manual feeding three times daily.

In the production trial, DO levels were maintained at a mean of 6.2 mg/L by high DO in the incoming water and by diffused aeration with air delivered through 10 air stones (22.9 cm x 3.8 cm x 3.8 cm) around the perimeter of the tank. In the last 12 weeks of the growout period, a 1/20-hp vertical lift pump was placed in the centre of the tank for additional aeration. Vigorous aeration vented carbon dioxide gas into the atmosphere and prevented its buildup. A high water exchange rate quickly removed suspended solids and toxic waste metabolites (ammonia and nitrite) from the rearing tank. A 1/2-hp in-line pump moved water at an average rate of 378 L/min from the sump to the rearing tank (mean retention time, 0.8 h). Values of ammonia-nitrogen and nitrite-nitrogen in the rearing tanks averaged 1.47 and 0.52 mg/L, respectively. A pH of 7.2 was maintained by frequently adding equal amounts of calcium hydroxide and potassium hydroxide. Total alkalinity averaged 56.5 mg/L as calcium carbonate.

In CA2 the vertical lift pump was eliminated, and the number of air stones around the rearing tank perimeter was increased to 22 (15.2 cm x 3.8 cm x 3.8 cm). With larger water volumes, the retention time will increase to an average of 1.37 hours.

Effluent from the fish rearing tanks flowed into two 1.9-m³ clarifiers in the production trial. Separate drains from two of the rearing tanks were connected to each clarifier [see Rakocay (1997) for a detailed description]. The clarifiers removed settleable solids, but the production of solids was not as great with the 9.5-minute retention time in the production trial as it had been in previous trials with longer retention times (>20 minutes). Therefore, in CA2 the clarifiers were increased in size to 3.8 m³ and the retention time is 19 minutes. The bottom slope of the new clarifiers is 45° as compared to 60° slopes in the 1.9-m³ clarifiers. Sludge is removed from the clarifiers three times daily.

Suspended solids levels, which decline slightly on passage through the clarifier, must be reduced further before the effluent enters the hydroponic tanks. Excessive solids are detrimental to plant growth. Solids adhere to plant roots, create anaerobic conditions and block nutrient uptake. Two filter tanks in series, each with a volume of 0.7 m³ and filled with orchard netting, receive effluent from the clarifier and remove considerable amounts of suspended solids, which adhere to the orchard netting. In the production trial, total suspended solids averaged 9.0 mg/L in the rearing tanks, 8.2 mg/L in the effluent from the clarifiers (a 9% reduction) and 4.5 mg/L in the effluent from the filter tanks (a 45% reduction). The filter tanks were drained and the orchard netting was washed with a high-pressure sprayer once or twice per week. Solids from the filter tanks and clarifiers were discharged through drain lines into two 16-m³ lined ponds, which were continuously aerated using air stones. As one pond was being filled over a 2 to 4-week period, water from the other pond was used to irrigate and fertilize field crops.

The relatively slow removal of solids from the system (twice/day from the clarifiers and 1-2 times/week from the filter tanks) is an important design feature. While solids remain in the system, they are mineralized. The generation of dissolved inorganic nutrients promotes vigorous plant growth. In addition, filter-tank solids create anaerobic zones where

denitrification occurs. As water flows through the accumulated organic matter on the orchard netting, nitrate ions are reduced to nitrogen gas. Nitrate is the predominant nutrient in aquaponic systems. High nitrate levels promote vegetative growth but inhibit fruiting. With fruiting plants such as tomatoes, low nitrate concentrations maximize fruit production. Nitrate levels can be controlled by regulating the cleaning frequency of the filter tanks. If the filter tanks are cleaned twice per week, there is less solids accumulation, less denitrification and higher nitrate levels. If the filter tanks are cleaned once per week, there is more solids accumulation, more denitrification and lower nitrate levels.

Organic decomposition in the filter tanks produces carbon dioxide, methane, hydrogen sulphide and other gases. If filter-tank effluent enters the hydroponic tanks directly, it retards the growth of plants near the inlet. Therefore, a 0.7 m³ degassing tank was added to the CA2 system. Filter-tank effluent enters the degassing tank and is vigorously aerated, venting potentially harmful gasses into the atmosphere. Degassing-tank effluent is split into three equal portions, each of which passes through a set of two hydroponic tanks. In each set of tanks, water flows 59.2 m before returning to the sump and being pumped back to the fish rearing tanks.

The hydroponic tanks retain the fish culture water for an average of three hours before it is returned to the fish rearing tanks. Each set of hydroponic tanks has 48 air stones (7.6 cm x 2.5 cm x 2.5 cm), located 1.22 m apart along the central axis of the tank, which re-aerate and mix the water, exposing it to a film of nitrifying bacteria that grows on the tank surface areas, especially the underside of the polystyrene sheets. In the production trial, DO increased from 4.0 to 6.9 mg/L on passage through the hydroponic tanks (Rakocy et al. 1997). Through direct nutrient uptake by plants or bacterial oxidation, Gloger et al. (1995) found that the UVI raft hydroponic tanks removed an average of 0.56 g of NH₃-N, 0.62 g of NO₂-N, 30.29 g of COD, 0.83 g of total nitrogen and 0.17 g of total phosphorous per m² of plant growing area per day using romaine lettuce. The maximum sustainable waste treatment capacity of raft hydroponics was found to be equivalent to a feeding rate of 180 g/m² of plant growing area/day. At the optimum design ratio of 57g of feed/m² of plant growing area/day needed to reduce nutrient accumulation, raft hydroponics has 200% excess waste treatment capacity. After an initial acclimation period of one month, it is not necessary to monitor ammonia or nitrite values in commercial-scale raft systems.

Several materials were used to construct the hydroponic tanks. The best construction materials consisted of poured concrete walls (40 cm high) and a 20-mil high-density polyethylene tank liner. The black liners used for CA1 absorbed considerable heat along the top of the tank walls. For CA2 the portion of the liners above the water level was painted white to reflect heat. A white liner that is resistant to UV light is also being tested. The polystyrene sheets were painted white with a potable grade latex paint to reflect heat and prevent the deterioration that results if it is exposed to direct sunlight.

There are several advantages to raft culture. There is no limitation on tank size. Rafts provide maximum exposure of the roots to the culture water and avoid clogging. The sheets shield the water from direct sunlight and maintain lower than ambient water temperatures, which is beneficial to plant growth. A disruption in pumping does not affect the plant's water supply. The sheets are easily moved along the channel to a harvesting point, where they are lifted out of the water and placed on supports at an elevation that is comfortable for workers.

A disadvantage of raft culture is that the plant roots are vulnerable to damage caused by zooplankton, snails and other aquatic organisms. Biological methods have been successful in controlling these invasive organisms. Ornamental fish, particularly tetras (*Gymnocorymbus ternetzi*), are effective in controlling zooplankton, and red ear sunfish (shellcrackers, *Lepomis microlophus*) are effective in controlling snails.

During the 2.5-year production trial for tilapia and lettuce in CA1, total annual production averaged 1,248 cases (Rakocy et al 1997). In 112 lettuce harvests, marketable production averaged 27 cases per week and ranged from 13-38 cases (24-30 heads/cs). Average harvest weight was 269 g for Sierra (red leaf), 327 g for Parris Island (romaine), 314 g for Jericho (romaine) and 265 g for Nevada (green leaf). The plants were weighed after the lower leaves were trimmed. Production was always greater during the cooler winter months when water temperature averaged 25.1°C than in the summer months when water temperature averaged 27.5°C.

Fish feed provided adequate levels of 10 of the 13 nutrients required for plant growth. The nutrients requiring supplementation were K, Ca and Fe. During the production trial, 168.48 kg of KOH, 34.48 kg of CaO, 142.9 kg of Ca(OH)₂ and 62.668 kg of iron chelate (10%) were added to the system, which was equivalent to the addition of 16.1, 3.3, 13.7 and 6.0 g, respectively, for every kilogram of feed added to the system. The amount of Ca and K added was the result of the quantity of base required to maintain pH at 7.2. Rainwater is used in all the aquaponic systems at UVI because the NaCl content of groundwater in the Virgin Islands is too high.

Two species of pathogenic root fungi (*Pythium myriotyllum* and *P. dissotium*) caused production to decline during the warmer months. *Pythium myriotyllum* causes root death while *P. dissotium* causes general retardation in the maturation rate of the plant. CA2 was designed to lower water temperature, through shading, reflective paint and heat dissipation manifolds (attached to the blowers), in an effort to minimize the effects of *Pythium*. A plant potting media containing coconut fibres (coir) is used to produce transplants for CA2 instead of the peat-based potting media used for CA1 because some peat products contain *Pythium* spores. A study is planned for the experimental systems to determine the effects of chillers and evaporative coolers on lettuce production, level of *Pythium*, water quality and system economics. The use of resistant varieties and antagonistic organisms also offer potential for *Pythium* control in aquaponic systems.

The only significant insect problem with lettuce was caused by caterpillars of the fall armyworm and corn earworm. These caterpillars were controlled by twice weekly sprays with *Bacillus thuringiensis*, a bacterial pathogen that is specific to caterpillars.

Hydroponic research in the CA2 system will evaluate production levels, planting densities, support structures and pest control techniques for a range of vegetable types, including cucumber, pole bean, snap pea, tomato, pepper, bush bean, squash, cantaloupe, watermelon, basil, pak choi and mustard green. Production output figures are needed to develop business plans. Research will also be conducted on the production of medicinal herbs and cut flowers.

Perspective

Cage culture in small watershed ponds, greenwater tank culture and aquaponics are intensive tilapia production systems that can be applied in areas that are not often considered as suitable for aquaculture development due to some resource limitation. The systems can be

applied on a hobby scale with experimental-sized units to supplement the family diet, or multiples of the larger units can be used to produce tilapia at commercial levels.

All of the systems developed at UVI represent appropriate or intermediate technology. The levels of complexity in constructing and operating these systems range from very simple for cage culture to moderately complex for aquaponics. A knowledge of dissolved oxygen, pH, alkalinity and nitrogen is important, but the greenwater tank and aquaponic systems can be operated by following a set of guidelines without a thorough understanding of the intricacies of water quality.

Capital input varies similarly. Small cages are inexpensive while aquaponic systems, even small ones, can be relatively expensive, considering the need for an assortment of tanks, a canopy, a water pump, an air blower, liners and floating sheets. The high output of fish and vegetables from aquaponic systems compensates for the cost.

One constraint in applying these systems in locations that are new to aquaculture is the availability of fingerlings. Adding a fingerling operation increases cost and complexity and may negatively impact the economics, especially for small-scale operations. The economies of scale of large commercial facilities will justify the addition of a fingerling production facility. The UVI research program is currently investigating the potential of small fingerling production facilities using small static tanks for breeding, a greenwater recirculating system for sex reversal and greenwater tank culture and clearwater recirculating systems for fingerling production.

Working on a dry and small Caribbean island in the Lesser Antilles, we are gratified at the enthusiasm and interest our research has generated, not only in the Virgin Islands but on several neighbouring islands as well. Many people are eager to raise fish for their local markets and are hungry for information. Most potential fish farmers do not have access to a pond for cage culture, so we generally recommend that they start with greenwater tank culture to gain experience, either on a hobby scale or a commercial size involving at least six tanks so that marketable fish are available monthly. We recommend small-scale aquaponics to those who are interested in fish and hydroponic plants, but we caution that large-scale aquaponics requires some preliminary experience or advanced technical training. We offer a short course annually on the UVI systems and plan to write detailed manuals for beginners. We are optimistic that tilapia culture will continue its phenomenal growth and that the concepts presented here will contribute to future expansion.

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Table 1. Summary of six greenwater tank culture experiments giving tilapia species (modified Florida red or *Oreochromis niloticus*), experimental treatment, stocking rate, stocking size, final size, growth rate, final biomass, feed conversion ratio (FCR) and survival. Values within each column of an experiment followed by the same letter are not significantly different ($P > 0.05$).

Experiment	Species	Treatment	Stocking Rate (#/m ³)	Stocking Size (g)	Final Size (g)	Growth Rate (g/d)	Final Biomass (kg/m ³)	FCR	Survival (%)
1	Red	Stocking rate	8	46	-----	2.8a	2.9a ¹	1.7a	93a
		Stocking rate	16	46	-----	2.8a	5.9b ¹	1.6a	95a
2	Red	No water exchange	12	94	-----	3.4c	6.5c ¹	1.9c	95c
		Water exchange-5%/d	12	94	-----	3.5c	6.8c ¹	1.8c	97c
3	Nile	Sludge removal	24	16.5	422d	2.4d	9.0d	1.60d	88.3d
		No sludge removal	24	16.5	364c	2.1c	7.6c	1.61d	86.3d
4	Nile	Sludge removal	26	71.5	514f	2.6f	13.4f	1.41f	99.3f
		No sludge removal	26	70.4	417g	2.1g	10.8g	1.51g	98.9f
5	Nile	25.8 g alum/ wk	17.8	194.7	947	4.35	16.0	1.79	97.6
		38.7 g alum/ wk	17.8	195.1	954	4.41	16.3	1.86	99.2
		51.5 g alum/ wk	17.8	201.3	1002	4.66	17.1	1.87	98.7
6	Nile	No alum	24	40.9	744h	3.4h	17.0h	1.56h	95.3h
		50 mg/L alum/wk	24	42.1	629h	2.8h	14.5h	1.55h	96.3h

¹ Yield

SCALLOP CULTURE IN BERMUDA: A MODEL FOR THE LESSER ANTILLES?

by

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INTRODUCTION

The development of aquaculture in Bermuda has been investigated at the Bermuda Biological Station for Research (BBSR) since 1987. BBSR is a Not for Profit Organization incorporated in the U.S., and obtains its funding from various sources. Aquaculture is an unprecedented activity in Bermuda; although, there is a long standing tradition of fishing, and of fish consumption by locals, there has never been any history of rearing marine organisms. In the past, Bermuda boasted plentiful populations of fish and shellfish. This is no longer the case for various reasons; hence aquaculture has been recently considered as a tool for both enhancing the natural populations and providing a reliable source of seafood product for local consumption.

The Bermudas are an isolated group of oceanic islands situated in the Northwest Atlantic Ocean (32°N and 64°W), surrounded by the Sargasso Sea. Despite its northern latitude, the presence of the Gulf Stream entrains a marine fauna and flora, which is very similar to that of the Caribbean. The entire 35km Long Island consists of seven major islands which are linked by bridges; this results in several semi-enclosed bodies of saltwater, referred to as inshore waters. There is no freshwater source in Bermuda. In the 1970's, residents and scientists alike observed the dramatic decline of several populations of finfish and shellfish in the inshore waters, generating a growing interest in the utilisation of aquaculture as a means of restoring the natural resources. As a first step to evaluate the feasibility of this type of activity into Bermuda, a workshop was hosted in 1983 at BBSR, with experts from the U.S.S. and Caribbean region. This paper will provide a brief background on the evolution of aquaculture in Bermuda, a synopsis of the culture method practised, and the current status of the program and conclude with the existing opportunities for the replication of this system in the Lesser Antilles

Results of Aquaculture Workshop, 1983

The 1983 Bermuda workshop conclusions favoured aquaculture in Bermuda, encouraging the focus on native and/or endemic species, and outlined some of the main advantages and disadvantages in conducting aquaculture activity in Bermuda.

The disadvantages were as follows:

- Little was known on the biology, growth requirements, and survival rates of potential culture candidate occurring in Bermuda's inshore waters; no basic data was available necessary for the culture techniques for the production of juveniles and adults.
 - Several economic disadvantages were outlined
1. Aquaculture is a labour intensive activity, and the cost of labour is very high in Bermuda, rendering possibly a high cost of production.
 2. The lack of available land for an aquaculture-type activity, related to the heavy exploitation of land in Bermuda (97%). Available sites for a land-based facility were scarce, and many of them were also prime sites for residential areas.
- The inadequate and limited existing legislation and policies regarding aquaculture. Encouragement and protection of aquaculture activity was therefore not present.
 - The multi-use of Bermuda's inshore waters by tour boat operators, recreational activities, and fishing. Thus, the section of an aquaculture site encompassed more than the biological requirements, but also incorporation into the existing traditional use of the inshore waters.

The main advantages outlined in favour of aquaculture development were the following:

1. Local seafood is a luxury commodity in Bermuda for both tourists and residents. This situation is due to the high import of finfish and shellfish, amounting to more than 80% of the seafood consumed. This implies the presence of an important local market.
2. The price of seafood is very high in Bermuda, and local products are more expensive than imported products. Prices for locally caught fish range from \$ 5.00 per lb. (wholesale) to \$ 10.00 per lb. (retail). Hence, it could be assumed that a cultured product would command a high market price.
3. Water quality is very good in Bermuda on the whole, despite the presence of some point sources of pollution. This is due to the high exchange rate with oceanic waters providing high dilution factors. Good water quality is a must for the set up of land-based facilities and for the successful growth and survival of animals in the field.
4. There is no income tax; whether corporate or individual. This facilitates the running of a small business.
5. The enforcement of an embargo on imported products is a possibility, providing assurance of sale of locally produced seafood. This is a common practice exercised by the Department of Enforcement for agricultural products. There are several criteria for this embargo to take place, namely the reliance of ample supply of local products, with a competitive price and comparative quality.
6. As aquaculture was an unprecedented activity on the island, and concerned parties (government bodies, funding sources and the general public) were relatively ignorant of the potential consequences often rendering them sceptical of the success of such an operation, a strategy of short-term goals with evaluations at every step was set-up. Results were demonstrated, discussed, and the subsequent steps agreed upon by the concerned parties, prior to continued funding.

The first step in developing a successful aquaculture program is in the well thought-out selection of a culture candidate.

Selection of a Culture Candidate

It was evident that in Bermuda, a tourist and offshore-based revenue where food security is not an issue, aquaculture would be a luxury operation. Furthermore, any production would be for local consumption only, as export to other countries would be difficult due to the high production costs, resulting in a lack of competitive prices on the international market. Finally, the species would preferentially be a locally occurring species as importation of species was frowned on by Bermudian scientists and government, in fear of impacting Bermuda's marine ecosystem. Hence, the selected candidate would have to be:

1. A native and/or endemic species to Bermuda
2. A luxury item, with a high market demand and associated high market price
3. A species with a rapid growth and survival rate, minimising any potential risks
4. Hardy and lend itself to culture techniques
5. Available in substantial numbers for the collection of a start up stock for research studies and as an initial broodstock required for controlled reproduction
6. Of interest to the general public for successful marketing and facilitate the raising of funds for research
7. A species with a low environmental impact to leave Bermuda's ecosystem unaffected by culture operations.

The animal selected as first candidate was the Bermuda sand scallop, *Euvola (Pecten) ziczac*. This animal was considered a delicacy by Bermudians, and was recreationally fished for local consumption in the past, it was relatively abundant in the inshore waters of Bermuda, inhabiting shallow sandy areas. Due partly to overfishing, partly to ecological changes, its population declined dramatically in the '70's putting it on the protected species list by 1978. The second scallop species considered was *Argopecten gibbus*, the calico scallop; this species was not as highly praised by Bermudians, but was nevertheless of value as an endemic scallop species. It was selected as a precautionary measure in ensuring a successful aquaculture operation, in the event that results proved discouraging for the sand scallop. The calico scallop was never found in high numbers in Bermuda, but was also placed on the protected species list in 1978 due to its low population numbers. Bivalves were considered a preferred candidate as their culture entrains minimal environmental impact compared to finfish culture

Both of these species have a wide distribution range throughout the sub-tropics and tropics, with Bermuda as the northernmost distribution. *Euvola ziczac* is distributed from Cape Hatteras, North Carolina through Gulf of Mexico and Caribbean to as far south as the state of Santa Catarina, Brazil. *Argopecten gibbus* ranges from slightly north of Cape Hatteras, North Carolina to Florida, throughout the Gulf of Mexico to the northern side of the Greater Antilles. In order to have some notion of the local market, a survey was conducted prior to the commencement of the program, attempting to evaluate the quantity of scallops imported on the island, a comparative demand with a local fresh product, and the potential price for a cultured Bermuda seafood. This survey consisted in part of a questionnaire sent to 35 restaurants and hotels. Results were very positive, confirming the demand, and the market for a local product, potentially overriding the use of imported frozen scallop meats. This candidate thus looked suitable for pursued investigations in culture techniques.

The constraints in culturing these two species was firstly, the lack of knowledge on the culture requirements ; neither of these species has been cultured on a large or commercial scale to our knowledge, although they both have supported a fishery at one time, in Brazil for *E. ziczac* and a current fishery off Cape Canaveral, Florida for *A. gibbus*. Secondly, there was a limited broodstock available in Bermuda for research studies on culture techniques; such that a broodstock first had to be reared in the case of *E. ziczac*, and imported in the case of *A. gibbus* in order to commence the program.

Brief History of the Programme: 1987-2002

The evolution of the project is divided below into three general phases.

Phase 1. Research on natural populations, behaviour and growth in the natural environment.

The program started as a student project, implying a small budget, in light of enhancing the natural populations of Bermuda's inshore waters. This objective was environmentally friendly, and generated interests in the general public, wishing to see their "backyard" revert back to the good old days when they could fish scallops out for lunch. Funds were therefore supplied by private sources, but with clear understanding that this was a preliminary project to assess the growth and survival rate of this species, and its hardiness in culture systems. Results of this program showed the potential for growth of these species, where adult/market size could be obtained in 12months, and a high survival rate of >90% from juvenile to adult stage in the field.

Phase 2. Focussed studies on controlled production in laboratory

A second phase was hence begun, considering juvenile production under controlled conditions. Interest was further generated by private individuals, in light of potential commercialisation, to optimise the production of juveniles under controlled conditions. Experiments were hence conducted at the Bermuda Biological Station for Research Inc. (BBSR) investigating the larval and post-larval rearing requirements for both these species. At the end of this phase, juvenile production proved successful, but the major constraint in pursuing this work was the lack of adequate hatchery/nursery facilities.

Phase 3. Expansion of techniques to large scale culture for both hatchery and grow-out.

Fortunately, the Bank of Bermuda granted us substantial funds for the continuation of the work in light of providing Bermuda with an alternative industry, and for the production of a reliable supply of seafood product to be consumed locally. Despite the increasing commercialism character in the project, work continued to be conducted at the Bermuda Biological Station under the umbrella of Research. This allowed for the approval and support of the government for the expansion of culture scale.

This paper will focus on Phase 3, outlining a synopsis of the culture techniques developed, and a summarised description of the purpose built facilities constructed at BBSR. This will provide a clear understanding of the available technology and of the modular hatchery designed at BBSR; both of which can be easily replicated in a similar sub-tropical/tropical environment.

Synopsis of Culture Techniques

One-year old broodstock is stimulated to spawn following exposure to a thermal shock. Eggs and sperm are collected separately, allowing for cross-fertilisation of the eggs. Fertilised eggs are distributed into 1000litre insulated larval tanks, filled with 1µm filtered seawater. D-larvae develop within 24hours; during the 12 day larval life, larvae are fed a daily diet of an algal mixture composed of algal species cultured on-site. At the end of their larval life, larvae metamorphose, developing a substrate-search behaviour enabling them to settle on various types of substrate. These pediveligers are settled on sieves made of Nitex mesh, and held in a raceway system with flowing filtered seawater. Settlement occurs over the next ten days, at which point post-larvae are referred to as spat. Spat are maintained in the nursery environment until they reach 5mm in shell height. . At this time, scallops have to be transferred to the natural environment. The easiest and most cost effective method for grow-out is the use of pearl nets, which are suspended on longlines 4' below the surface. During this phase, culturing techniques consist of grading scallops to reduced densities as they grow, and cleaning of nets on a three months basis to prevent fouling and decreased flow, entraining mortalities. The whole cycle takes approximately one year which is relatively rapid for a bivalve, during which scallops attain 50mm shell height.

In summary, there are therefore three stages to bivalve culture:

1. Hatchery phase, which requires a land-based facility, and involves the production of larvae;
2. Nursery phase, which is also land-based and involves the production of spat or seed; and
3. Grow-out phase, which occurs in the natural environment and allows for the rearing of juvenile scallops to adult size. The construction of the hatchery/nursery facilities for large-scale production of larvae and spat was the main point of focus during Phase 3.

Modular Scallop Hatchery

The constraints in building a hatchery in Bermuda were the limited land availability, and the short window between the granting of the funds and the spawning season, when a functional facility was required. In light of this, a low cost "temporary" hatchery was built in June 1999 based on three refrigerated "reefer" containers. This facility was designed and fitted for larval and post-larval rearing of bivalve species; the main goals were to develop techniques for large-scale production and to conduct experimental work towards optimising culture techniques for all stages of scallop life cycle. Flexibility of usage was a fundamental part of this model hatchery. This facility has now been in use for three spawning seasons, and has proved compact and efficient for the rearing of scallop species.

Hatchery and nursery facilities are compactly arranged in 2x20' insulated, air-conditioned, glass-fibre containers with an additional 12' container dedicated to algal culture. Culture facilities comprise:

1. An independent seawater system providing a continuous supply of filtered seawater.
2. A temperature control system for seawater in support of broodstock conditioning and requirements for larval and juvenile rearing.

3. 1000 litre insulated polyethylene and 200 litre conical, glass-fibre tanks for standard larval rearing in closed systems, and for experimental rearing in flow-through larvae culture systems.
4. Flexible usage 450 litre round tanks, and stacked raceways for setting pediveligers and growing spat. Raceways may be either connected together as a single open-flow or semi-recirculating system, or used independently of one another, or as holding tanks for a series of small, independent aquaria.

Hatchery and Nursery Facilities

One of the interconnected containers forms the hatchery area, accommodating 4 semi-square 1 000 litre insulated tanks. These are used for conventional, closed system rearing of bivalve larvae. These tanks have proved very reliable in rearing scallop larvae, maintaining temperature within 1°C of the required for a 72h period. In addition, there are three 200 litre conical tanks currently used for experimental work in flow-through larval rearing. A total tank volume of 4 600 litres is therefore available for larval rearing.

The nursery area, occupying the other linked container, has been designed for flexible use in setting procedures and for early nursery culture. Two 450 litre circular tanks are available as either closed or open systems for setting larvae on collector mesh. Two 6' x 2' x 0.5' deep flow-troughs are mounted on a side-wall, one above the other, acting as raceways. They are connected to a sump tank of 220 litre capacity fitted with a small pump and 250W heaters to deliver water to either or both troughs at the required temperature through water delivery pipe work. This system is extremely versatile; each raceway can be used independently as an open, closed, or recirculating system. This allows for the setting of larvae on sieves, conducting experiments in a series of independent aquaria, or using both raceways as one larger system with a total capacity of 510 litres, in, for example, the early nursery culture of spat.

Algae

The independent algal culture container is fitted for the UV light disinfection of prior 1 µm filtered, ambient temperature seawater. Cultures of a variety of useful algae species range in scale from 500 ml flasks to 100 litre tanks. They are maintained in a climate controlled environment with 24 h a day illumination, and are continuously supplied with a mixture of air and CO₂. The current maximum output of about 100 litres per day is sufficient for the current operations of the hatchery / nursery facility.

Current Production

The current capacity of the hatchery/nursery facilities equate the production of 250 000 5mm spat, which would lead to approx. 200 000 adult scallops or 13 tonnes of live weight. Production has not attained maximum capacity over the past three years as there has been no need for it at this time. Hence, the actual production of the aquaculture facility at BBSR was of 1 tonne live fresh weight of scallops in 2001, and of 5 tonnes of live fresh weight of scallops in 2002. Five tonnes of scallops equals approx. 80 000 market size (>45mm shell height) of scallops. A staff of four people is present during the spawning season, manning the hatchery/nursery, algal cultures and grow-out; during the off-season, staff is decreased to 2 people managing the grow-out.

Marketing of Product

Production techniques for rearing scallops on a relatively large scale were therefore complete; the question now lay in the marketing and selling of scallops to the local market. Marketing

is a key issue in aquaculture, one which is often overlooked by aquaculturists; however, this is truly the component which will render an operation viable. In order to explore the Bermuda market, sample baskets were provided to various chefs around the island. Responses were very positive, and sales to selected restaurants were initiated in 2001. Scallops are sold at a high price of \$ 1.00 a piece, a value within those attributed to local seafood products and some imported products. The outlook for commercialisation was promising. However, for full commercialisation to take place, several issues need to be addressed.

Aquaculture Permits

Up to the present, aquaculture activity in Bermuda has been conducted under the umbrella of research. This has facilitated the administrative procedures in obtaining permits for various aspects of this type of operation. The only permit needed at present has been that allowing the sale of the cultured animals. However, with the development of the program, and its increasing evolution towards commercialisation, the following issues need to be addressed and resolved by the respective administrative bodies.

- A. The species cultured in Bermuda are on the protected species list; hence a policy needs to be devised with the Ministry of the Environment (Department of Enforcement) which provides a simple and efficient method for tracking the source of sold scallops to the culture operation. This prevents poaching and fishing of animals from the protected natural populations.
- B. The grow-out areas consisting of longlines should be zoned and marked as aquaculture areas. Due to the high traffic of small boats in the inshore waters of Bermuda, these areas can only restrict anchoring and mooring, but allow for the passage of small boats. This policy has been agreed with the Ports Authority in Bermuda, providing that longlines are submerged 2-3m below the surface. Surface markers at every corner would delineate the boundaries, for which an annual fee would be levied, as for a mooring.
- C. As longlines occupy an area above the seabed, as does a dock for instance, an agreement on a lease for the seabed needs to be agreed with the Ministry of Works & Engineering
- D. Should a more permanent hatchery be built, the zoning of the land as an industrial and non-resident area would have to be taken into consideration, and permission for building would be required by the Department of Planning. Strict regulations are enforced in Bermuda on the type of buildings erected, and the sites chosen for these.

Extension to Private Sector: Phase 1

Although the logistics of developing aquaculture in Bermuda are not simple due mainly to the lack of precedence, extension of the program to the private sector needs to be considered for continuation of aquaculture on this island. The investment for building a hatchery, the set-up costs, running costs, training of individuals, and time required are a deterrent to a private sector which has no history of aquaculture activity. Hence, it is important to devise a system of expansion which is user friendly, with minimal investment, and which proves successful on the short-term. The current proposal put forth by BBSR is the selling of a small and manageable number of juveniles (25mm) to one or several selected candidates. To minimise investment, the equipment required for grow-out is provided by BBSR, as well as the existing longline systems for a period of one year. Following hands-on training by BBSR aquaculture

staff, growers become responsible for rearing scallops to market size, harvesting and selling them to restaurants of their choice under their name. The lending of grow-out equipment would be viable for a period of 1 1/2 year, when all scallops should be sold. The appeal of this system to the growers lie in the minimal financial investment and low technology required; furthermore, a return on investment with a profit should be made within one year if proper procedures are followed. This initial demonstration is heavily subsidised by BBSR in terms of support and equipment as it needs to be successful, and show the viability and profit-making potential of scallop culture in Bermuda. In this way only will aquaculture move ahead on this Island. Simultaneously, it is also necessary for BBSR to maintain a pilot grow-out farm as an example to growers, and as an assurance that proper culture techniques entail a reliable seafood production. The Department of Enforcement has approved this program, and gives its support in providing the selected candidates with an aquaculturist registration, and a permit to sell cultured scallops to restaurants. This program will commence in December 2002.

Summary of Aquaculture Programme in Bermuda

This program began in 1987, and has been running intermittently since. The major downfall of the entire project has been the lack of continuity in funding, forcing it to stop and re-start with several years interval in between; this yields a lack of continuity in research, in the trained staff, and in the availability of a good broodstock of scallops. For this main reason, further compounded by the small budgets made available and the inadequate facilities utilised, the evolution of the program was slow. Moreover, the Ministry of the Environment was non-committal during the first few years, rendering administrative procedures slow. The general lack of support coupled with the limited information on the requirements for culturing these species, reduced the program to a snail's pace. It has only been since 1999, when funds were made available for a facility, and for a small staff, that the project advanced rapidly. However, it must be noted that the driving force behind this program since its inception was the knowledge that the market demand was present, and that it would command a high price.

Replication in the Lesser Antilles

A turn-key operation, with a well tested technology, a production of juveniles, and a modular hatchery is now available. The species reared are tropical and sub-tropical and should prove to perform well in the Caribbean region. The modular hatchery can be easily replicated, with the only requirement being that of access to good seawater. Moreover, this hatchery can obviously be utilised for other bivalve species. The grow-out systems differ for both species of scallops, and depending on the nature of the island, the best system may be adapted for successful culturing. Calico scallops are reared on longlines, in semi-protected bays with a minimal depth of 10m. Sand scallops are reared on sandy bottoms, in protected shallow bays of preferably 2-3m depth. The whole culture system could be easily adapted to Caribbean islands, as aquaculture in Bermuda faces many of the same constraints as those faced by several Caribbean islands. In order to transfer and implement this technology successfully to other areas, a stepwise approach should be considered:

- The market demand for scallops in the Caribbean region. According to FAO statistics, in 2001, 5 tonnes of scallops were imported into the region. Scallops may be imported in various forms, as for example, packages of frozen muscle, or in the shell. The preferred form utilised in the Caribbean needs to be investigated through a market survey. The potential price is also of importance,

taking into consideration that a fresh seafood product often commands a higher price than a frozen product.

- The grow-out of juveniles to market size in the natural environment needs to be determined in the selected area. The available seed from the BBSR hatchery facilitates this phase, and a trial period of 8-12 months is sufficient to determine the growth and survival rate of the species in its new environment. The only investment is the purchase of seed and grow-out equipment.
- The reproductive cycle of the species in the Caribbean region needs to be evaluated. This is of importance should hatchery production be considered in the future.
- The import of a modular hatchery. The current hatchery used at BBSR may be easily replicated in a container, and shipped to any desired location in the Caribbean.

Current Transfer of Technology Programme

There are currently two programs underway for the transfer of scallop culture technology from Bermuda to the Caribbean region.

The first is one with the Turks and Caicos Conch Farm in Providenciales, TCI. This project is a 12-months trial for the grow-out of the sand scallop in existing conch parks located in a protected sandy bay. Approximately, 1000 juveniles (25mm shell height) are sent from BBSR hatchery and distributed in the conch parks for determination of growth and survival rate in the Turks and Caicos Islands. The purpose is to develop scallop culture on a commercial scale in these islands complementing the current culture of conch, *Strombus gigas*.

The second is a proposed technical cooperation program (TCP) between Cuba and Bermuda, sponsored by the FAO of the UN, for the implementation of scallop culture in Cuba. This proposal is currently being assembled; it is a two year program, where the first year is one of grow-out evaluation on an experimental scale, and the second year is one of expanding to the Fisheries Enterprises on a commercial scale.

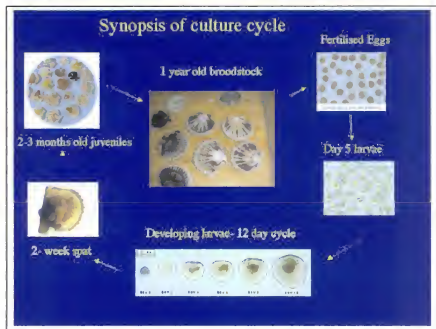
Both of these programs are the first in transferring the technology outside of Bermuda. BBSR has in its mission a strong component of education and training, necessary to these types of programs. This mission statement coupled with the infrastructure and scientific support available, render BBSR a useful link to the rest of the Caribbean region for sustainable aquaculture development.



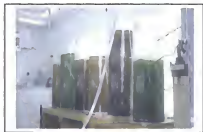
Sand scallop *Euvola (Pecten) ziczac*



Calico scallop *Argopecten gibbus*



Synopsis of scallop culture cycle in Bermuda



Algal culture in 100 litre vessels



Tanks for spat settlement and rearing

ENABLING POLICY FRAMEWORKS FOR THE PROMOTION OF AQUACULTURE DEVELOPMENT IN THE LESSER ANTILLES

by

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INTRODUCTION

The fisheries sector generally plays a minor role in the Small Island Developing States (SIDS) of the Lesser Antilles. The contribution of the sector to the national economies of the Lesser Antilles countries is often less than two percent of their Gross Domestic Product (GDP). The service sector (including tourism and financial services) is much more important to the national economies, in terms of income, employment and contribution to the GDP. Still, the fisheries sector in should be considered as important in terms of its contribution to the daily diet of the islands population. Fish proteins take up between 14% (Trinidad and Tobago and St. Vincent and the Grenadines) and 22% (Antigua and Barbuda) of the total animal proteins consumed by the population.

As the populations of the islands continue to increase, between 0.2% per annum in St. Kitts & Nevis and 1.4% per annum in St. Lucia and the Bahamas (World Bank, 2001), and as capture fisheries continue to fluctuate, aquaculture development could play a role in guaranteeing a stable and sufficient supply of fisheries products to the islands' populations.

The members states of the Caribbean Community and Common Market (CARICOM), recognized in their 1998 amendment to the treaty establishing CARICOM (protocol V: *Agricultural Policy*), that aquaculture development programmes should be established. Under this protocol, it is stated that "aquaculture development should facilitate and promote the development, management and conservation of the fisheries resources in and among member states on a sustainable basis."

Aquaculture production in the SIDS of the Lesser Antilles (Trinidad and Tobago, Dominica, Grenada, Saint Lucia, Saint Kitts and Nevis) has increased from 2 metric tonnes in 1990 till 39 MT in the year 2000. On the other hand, the aquaculture production of the Bahamas has decreased over the same period from 49 mt to only 2 mt. Seen in the perspective of the Caribbean as a whole the aquaculture production in the SIDS of the Lesser Antilles and the Bahamas is less than 0.1 percent of the total Caribbean aquaculture production. Causes of this limited aquaculture development are numerous and have technical, biological, environmental, economical, social, legal and political backgrounds. In the following paragraphs some of

these causes will be discussed and specifically aquaculture development constraining and promoting policies will be reviewed.

PREREQUISITES FOR AQUACULTURE DEVELOPMENT IN THE SIDS

The opportunities for aquaculture development depend on the availability of sufficient land/water *sites* for aquaculture. For freshwater aquaculture, which is currently practiced much more than marine aquaculture in the SIDS of the Lesser Antilles, freshwater resources are needed that provide a sufficient quantity of good quality water when needed. In contrast, for marine aquaculture development there should be locations that are suitable for this purpose. The interaction with other aquatic *environment* users is obvious for both activities (fresh as well as marine aquaculture); therefore negative impacts of aquaculture on other activities should be limited or avoided. Similarly, the effects of other activities should not harm aquaculture production (e.g. industrial and city wastewater might pollute nearby aquaculture farms). Environmental Impact Assessments (EIAs) are in many European countries (UK, Netherlands, Germany, Denmark, and Greece) requested to those willing to start up aquaculture enterprises. Whether they are requested or not often is conditional upon the scale of production and expected pollution in the waste (water) of the farm.

Another critical factor is the decision on the choice of *species(s)*. The species to be produced should be suitable for the local situation in the SIDS of the Lesser Antilles, i.e. water temperature, water quality. *Feed* should be available, reproduction should be technically possible, and last but not least there should be *consumer demand* for the specie selected and opportunities for potential increase in demand locally or in accessible markets. The limited size of many local *markets* in the SIDS of the Lesser Antilles and the (in some cases) considerable distance from other potential markets, requires careful examination of possible alternative marketing channels and approaches.

Managerial factors should be considered as well as aquaculture development requires capacity on technical issues as for instance pond management as well as people with knowledge and expertise about the *management* of farms/enterprises. Farmers in the SIDS of the Lesser Antilles are currently facing problems in selecting environmentally sustainable aquaculture production *technologies*. Mechanisms for acquisition of *information* are not easily accessible and, as a result, many pilot schemes have, more often than not, failed. Therefore, the selection of appropriate technologies at the farmer and entrepreneurial level is crucial (FAO, 1998).

As important as biological and technical feasibility is *economic viability* (Ridler & Hishamunda, 2001). Numerous attempts to develop aquaculture with the main goal of providing high value protein to the rural population in developing countries have failed as (even small-scale) farmers were less interested in producing for home consumption than in producing for the market. For aquaculture to develop, demand for the product must exist, and with the promise that farm-gate price will exceed per unit production cost (Ridler & Hishamunda, 2001). Economic viability of aquaculture (shown by sectoral profit figures, business plans and financial analysis) will facilitate the investment in the sector and allow farmers/entrepreneurs to increase access to *credit* to establish and develop their aquaculture business.

The accessibility to financial services as for instance credit, savings, money transfer services and insurance is beneficial to the development of the sector. With regard to *insurance*, this is especially an issue in the SIDS of the Lesser Antilles as *natural disasters* (mainly hurricanes and storms) are frequently interfering with the establishment of (aquaculture) businesses.

Aquaculture development in the SIDS could benefit from the existing capture fisheries sector institutional framework, its *affiliated industries* (e.g. post harvest processing, nets and other inputs importers, domestic market fish wholesalers and fishery products exporters) and the *infrastructure* already established (e.g. cold storage, harbours, markets, ice plants and processing facilities).

The development of aquaculture should be *socially* acceptable as well; this will make it possible that investments in aquaculture infrastructure will be allowed. In this respect, in some countries (e.g. France, Australia and USA) shrimp aquaculture has received a lot of negative media attention (mainly related to its sometimes negative environmental impacts) which might result in some sort of public resistance towards new establishments of shrimp culture in these countries.

The existence of good aquaculture *legislation* can provide an important contribution to sustainable aquaculture development; moreover, it can limit (or avoid) environmental damage and can contribute to the development of an environment in which aquaculture is economically viable (Percy & Hishamunda, 2001). Issues as right to property, right to sufficient clean water and avoidance of unnecessary cost (e.g. by using a single window approach) should be addressed in aquaculture legislation. Enforcement of the rules and regulations should be part of any good aquaculture legislation; a permit or *license system* might provide a solution here.

In SIDS, with few exceptions, there is a total lack of, or a very limited, institutional and financial capability to allocate resources for *promotion* or development of aquaculture. This sub sector has, in general, been given scarce economic weight, due to either the recent introduction of aquaculture in some SIDS, or to the lack of awareness of its potential. As a consequence, the SIDS of the Lesser Antilles experience common problems with aquaculture development *planning* and, therefore, often have similar requirements for information on production technology and on the marketing of aquaculture products (FAO, 1998). In addition to the above points the *macro political* situation as well as the level and kinds of *government involvement* with business operations is affecting the development of aquaculture.

MACRO ECONOMIC AND SECTOR SPECIFIC POLICIES

The aquaculture sector is not (yet) considered as one of the main contributors to the social and economic development of the SIDS of the Lesser Antilles. However, as sub-sector of the fisheries sector aquaculture is considered in an amendment of the Treaty establishing the Caribbean Community and Common Market (CARICOM), (Chaguaramas, 1973), namely "Protocol V: Agricultural Policy" (1998). It is also considered in the recent CARICOM Agreement establishing the *Caribbean Regional Fisheries Mechanism* (CRFM) (2002). In Protocol V of the CARICOM agreement the issue of "establishment of development plans for aquaculture" is raised (under article 49a). The CRFM agreement states more specifically that "the CRFM shall be guided by the principle of promoting aquaculture as a means of

enhancing employment opportunities and food security, nationally and regionally” (article 5: General Principles, sub-paragraph f).

The CRFM agreement further states that the member parties are “aware of the relevant provisions of the United Nations Convention on the Law of the Sea (1982); the FAO Code of Conduct for Responsible Fisheries (1995); the Agreement to promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas (1993); the United Nations Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks (1995); Sustainable Development of the Programme of Action for Small Island Developing States (1994) and the Protocol Concerning Specially Protected Areas and Wildlife in the Wider Caribbean (1990).”

With respect to aquaculture the reference above to the *Code of Conduct for Responsible Fisheries* (CCRF) is specifically important as the CCRF contains specific articles with valuable guidelines related to aquaculture development (article 9, please see annex 1) and developing countries (article 5).

Internationally, at the twenty-first session of the *Committee on Fisheries* (COFI), held in Rome, March 1995, “some delegations underscored the potential importance that the development of aquaculture might play in future in SIDS. It was noted that aquaculture could be vital for food and economic development, and could permit a reduction in fishing effort where this was called for” (paragraph 38 of the report). At the same session several delegations considered FAO assistance to SIDS should assign priority to six areas, among which “aquaculture and inland fisheries conservation, management and development”.

At the twenty-second session of COFI, held in Rome, March 1997, the six priority areas were confirmed and “the elaboration of the FAO Programme of Fisheries Assistance for Small Island Developing States, as strongly endorsed by the Alliance of Small Island Developing States, was appreciated. FAO was urged to proceed with the Programme’s implementation without delay, however no donors could be found for the elaborated programme.

At the twenty-third session of COFI, held in Rome, February 1999, COFI “expressed its support for the FAO Programme of Fisheries Assistance for Small Island States but was concerned with the limited progress achieved in securing funding for the Programme”. Similarly “Several Small Island Developing States (SIDS) expressed their concern that the special programme for SIDS had not materialized due to the lack of funding” at the twenty-fourth session of COFI held in Rome February-March 2001. While in the twenty-third session the issue of fisheries and aquaculture development in the SIDS received considerable attention, there seemed to be a lack of interest during the twenty-fourth session to follow up on the earlier discussions.

At the first session of the Committee on Fisheries: Sub-Committee on Aquaculture (SCA) held in Beijing, China, 18-22 April 2002, “some delegates noted the importance of aquaculture for small island developing States, as well as the potential for the culture of ornamental fishes and live fish feed” (FAO, 2002).

From the above it can be concluded that aquaculture development in the SIDS (including the SIDS of the Lesser Antilles) is still on the international agenda; indicating that importance is given to its development. However, at the same time it is clear that the international community is not giving priority to assisting the SIDS in the development of aquaculture.

The CRFM should therefore be regarded as a good step forward, taking regional level initiative in aquaculture development.

Although not making specific reference to SIDS, the outcomes of the "Conference on Aquaculture Development in the Third Millennium" considered priorities and strategies for development of aquaculture in the next two decades, in the light of future economic, social and environmental issues and advances in technologies (FAO, 2001). The resulting Bangkok Declaration and Strategy for aquaculture Development beyond 2000 is frequently used as background document in the formulation process of aquaculture development strategies worldwide, and could be of value to those SIDS of the Lesser Antilles planning their strategies.

Apart from fisheries sector related policies it should be noted here that general non-sector specific macro-economic policies are critical to aquaculture development opportunities as well. In this respect one could think of enabling policies that would include good governance, openness to trade and macro-economic growth, and emphasis on private investment (Ridler & Hishamunda, 2001).

Good governance is essential to reducing poverty and economic growth. It can be defined as public institutions functioning transparently, accountably and responsively to citizens (Temple, 1999). Good governance includes administrative and managerial processes being well arranged by the government; their ministries and other (local) governments need to be effective and productive. Characteristics of good governance are participation of the population in governing and policy development/implementation, as well as using democratic procedures, separate of powers and respect human rights.

Political stability is a major factor contributing to economic growth and investment, as well as taxation schemes, legal systems and *soft and hard infrastructure* (Education, financial and health systems, transport, communication, etc.). Countries with lack of political stability encounter difficulties in attracting foreign direct investments (e.g. Zimbabwe, Ivory Coast, Venezuela, and Colombia). High taxes discourage investment while free trade zones, *tax holidays* and *rebates* show in increase investments as they are supportive in forming a favourable business environment. Good governance implies also that there exists a *legal framework* that provides clarity on *property rights* issues (ownership, transfer, length of lease/usufruct rights), shows coherence and harmonization between various sectors, addresses inequalities and is transparent. The co-operation among the CARICOM Governments under various treaties and agreements is important as it addresses issues that are relevant and of common concern to all member states of the Caribbean community. Some of those include: the agreement for the avoidance of double taxation and the prevention of fiscal evasion with respect to taxes on income profits or gains, capital gains for the encouragement of regional trade and investment and the harmonizing acts on various issues such as trade unions, employment and fiscal incentives

Corruption is one of the main factors constraining poverty alleviation and economic growth. Sectors such as agriculture and aquaculture, where investments are generally made for the long term attract less foreign direct investment as a consequence; which is harmful for their development. The World Bank states that an effective anticorruption strategy builds on five key elements: 1) Increasing Political Accountability; 2) Strengthening Civil Society Participation; 3) Creating a Competitive Private Sector; 4) Institutional Restraints on Power; and 5) Improving Public Sector Management. Starting-up aquaculture entrepreneurs are

highly reliant on the provision of public services, and are generally not capable of paying the extra costs associated with bribery, fraud, and the misappropriation of economic and other privileges. Corruption is thus also constraining aquaculture development.

In creating a favourable business environment addressing issues as *financial infrastructure* development are necessary for the national governments. Every business (starting-up as well as mature) needs access to banking services, credit and insurance in order to be able to work effectively. Most of the SIDS of the Lesser Antilles are well equipped with financial institutions that can provide these services, although part of the financial sector (specifically those institutions providing insurance) have suffered from the natural and man-made disasters lately, which made some go bankrupt and others restructure their programme.

Openness to trade and *macro economic growth policies* are positive determinants of private investment (Ridler & Hishamunda, 2001). A sector like the fisheries sector is largely dependent on private investment; for instance in vessels, ponds, hatcheries processing plants. Public investment is also important but is generally limited to infrastructure (ports, roads and communication) and education and extension. Government policies that support economic growth, for instance through maintaining low inflation levels, low interest rates, low national budget deficits (or even better having surpluses) and stabilizing exchange rates at realistic levels, will automatically contribute to the creation of an environment in which private investment (also in aquaculture) flourishes.

International, regional and bilateral trade agreements, specifically the ongoing establishment of the CARICOM “*Single Market and Economy*” (CSME) can be important stimulants to the development of the fisheries sector. At *regional level* the CARICOM countries have signed agreements on a Caribbean Court of Justice, Free movement of goods, Free movement of skills. Free movement of capital and capital market integration are still under negotiation within CARICOM. In view of the significant task in preparing the region to compete effectively in the increasingly global market place the establishment of the Regional Negotiating Machinery is important as it contributes to the region’s capacity to effectively negotiate for Caribbean interests in international fora and agreements.

Some trade agreements signed between CARICOM and other parties, with relevance for exports and imports of aquaculture products, are among others:

1. Caribbean Basin Initiative (CBI) that gives all CARICOM members (excluding Suriname) access to the US Market.
2. CARIBCAN which provides for access to the Canadian market.
3. Cotonou Agreement (2000) and the EU General System of Preferences (GSP) which provide a framework for supporting the mutual trade and development aid between African, Caribbean and Pacific (ACP) countries and the European Union.

In contrast to the above trade agreements, the national governments in the SIDS could also promote the aquaculture sector development by establishing *trade-barriers* (e.g. using tariffs that shield the domestic aquaculture sector from foreign competition). Using the *infant-industry* argument governments can allow their sectors to grow for a certain period, lowering the foreign competition till such a sector is mature and ready to compete at more or less equal levels. For small sectors like aquaculture, which products generally compete with those of the capture fisheries sector, establishing such barriers seems less appropriate. Particularly in view

of the need for import of certain inputs (e.g. feeds and chemicals/drugs) as no industries providing these inputs are available in some of the SIDS of the Lesser Antilles.

Many SIDS of the Lesser Antilles have benefited or are still benefiting from development programs such as World Bank funded emergency recovery and poverty reduction projects and Inter-American Development Bank (IDB) funded agricultural sector reform programmes (e.g. in Trinidad & Tobago). These development banks urge the loan obtaining governments to implement the, in their opinion, right policies that generally include trade liberalization policies and measures.

As discussed above a well designed legal and regulatory framework is a prerequisite for aquaculture development. Such a framework should be practically and its implementation should be as cost-effective as possible. Many countries, among which most SIDS of the Lesser Antilles (e.g. Dominica, Grenada, St. Kitts and Nevis, Trinidad and Tobago) have fisheries laws that address environmental issues; often with the aim to reduce negative externalities (e.g. pollution, environmental degradation, overexploitation, conflicts over resource ownership and use). Specific aquaculture related regulations generally include procedures for obtaining permits or licenses, tradable or non-tradability of permits, EIA requirements and bureaucratic procedures. Absence of specific aquaculture *legislation* and regulation may handicap development of the sector (Ridler & Hishamunda, 2001). The majority of the SIDS of the Lesser Antilles does not have a specific aquaculture legislation (yet), nor procedures for EIAs and Codes of Best Practice. Countries like Dominica and Grenada address issues such as controls on the introduction and import of exotic/non-indigenous fish species. However, not all SIDS of the Lesser Antilles have such policies yet or do not implement the policies properly.

Finally, governments have a role to play in increasing *public confidence* in the sustainable development of the sector, through addressing issues of public concern in a fair and transparent manner. Investment in *science* and risk management approaches to be able to provide the population with clear and concise information on health, safety and environmental issues is required.

AQUACULTURE PROMOTING POLICIES AT FARM LEVEL

Governments of the SIDS of the Lesser Antilles, possessing an aquaculture sector that cannot be considered mature yet and seeing aquaculture as a means of enhancing opportunities for employment and food security, could decide to intervene at farm level to promote the sectors' development.

Possible government interventions, at the farm level, could include:

- Starting-up grants and subsidizing inputs,
- Providing guarantees for commercial loans to starting aquaculture entrepreneurs, financial and technical support to farm level research,
- Providing extension services and supporting fingerling production and availability through government hatcheries,
- Assisting starting-up entrepreneurs in developing their business plans and carrying out financial and economic analyses, and
- Providing duty and tax exemptions or tax holidays to starting entrepreneurs.

Some of the SIDS of the Lesser Antilles already apply exemptions of duty and taxes for aquaculture (e.g. St. Lucia), while other countries' governments provide policy assistance to the sector and free of charge technical expertise and extension services.

Government assistance to starting aquaculture entrepreneurs is well accepted in many countries. A large number of governments support *education, research and extension services* in aquaculture (e.g. EU, USA, Japan, Vietnam, Chile, PR China, etc.). This support has direct effect on the interest in aquaculture as it creates awareness on aquaculture products, technologies and production processes. In a number of countries (e.g. Netherlands, Canada, Norway, France, etc.) public-private partnerships in the aquaculture sector carry out research on various aquaculture related issues, such as: technology development, fish feed improvements, environmentally and socially sustainable production processes, vertical chain marketing of aquaculture products, etc.

Starting-up aquaculture entrepreneurs generally lack access to credit, as commercial banks require collateral and relatively large own investments. Some governments (e.g. Madagascar, Netherlands) assist starting entrepreneurs to write *business plans* and carry out *financial and economic feasibility analysis*, which can be used to show banks that the plans are viable. This is especially necessary as many banks hesitate to invest in aquaculture because of the expected risks involved (related to culture of life animals). Other governments have established credit programmes or provide funds to commercial banks to maintain credit programmes that work with subsidized interest rates and less restrictive conditions (e.g. prolonged payback periods), making loans to sector cheaper. In this respect it is worthwhile to mention that in many countries there exist NGOs, investors and development projects that are sometimes willing to provide cheap loans to support aquaculture development.

Innovation in aquaculture is often supported by the government (e.g. the EU Aquaflow and Small and Medium Enterprise (SME) Research programme). Some provide starting up *grants* to innovative initiatives, give *tax holidays* or allow starters to employ labourers with *subsidized salaries* or *tax exemptions*.

In order to develop a sustainable aquaculture sector, the *affiliated industries* should be developed as well at the same time (as discussed in chapter 2), so that aquaculture entrepreneurs can access sufficient supplies of inputs (e.g. fingerlings, feed, chemicals and drugs). This will enable them to market their products. Especially in Africa and South East Asia there are many governments (e.g. Uganda, Ghana, Vietnam and PR China) that support the development of the sector through construction and maintaining *hatcheries* that provide the necessary fingerlings to the sector. However, caution should be taken here as such government hatcheries sometimes hamper the development of the sector at a later stage, as competition is less chance to develop when subsidized government fingerling production is around.

As mentioned earlier the role of the government in *regulation* the development of the sector is important. Individual entrepreneurs should receive clear instructions on what is allowed and what not. Administrative procedures for obtaining *permits* should be kept to a minimum and be as simple as possible (e.g. using a single window approach for obtaining all necessary documents). A permit system that includes issues of access to land and water resources and clearly defines rights and obligations of the permit holder has shown to be a helpful tool for many aquaculture entrepreneurs. Moreover, under public-private partnerships developed

codes of practice that practically address the environmental, technical, social and economical sustainability of aquaculture have proven to be (e.g. in Thailand, United Kingdom, Germany) valuable guides for individual aquaculture entrepreneurs in the development of their businesses.

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The subregional workshop aimed at facilitating greater understanding of the issues involved in creating the required enabling environment for sustainable aquaculture development in the Lesser Antilles was held in Vieux Fort, Saint Lucia from 4 to 7 November 2002. Following the sharing of national experiences and the presentation of selected case studies on ongoing subregional aquaculture activities, the issues that have constrained past aquaculture development activities were discussed. The participants recognized the diversities in both the scale and success of past aquaculture activities in the subregion and identified the constraints to and opportunities for sustainable aquaculture development in the subregion. The workshop highlighted the need for subregional governments to establish transparent aquaculture development policies using mechanisms for consultation with other stakeholders. Regional cooperation and the need to focus on an integrated approach to aquaculture, to ensure responsible practices and contribution to food security, were also emphasized.

ISBN 92-6-104953-8 ISSN 0470-8837



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FRANCE 48218/1/03 03-1000